HYGIENE

AND

PUBLIC HEALTH

VOL. I.

A TREATISE

ON

HYGIENE AND PUBLIC HEALTH

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PREFACE

It is now some years since the late Professor De Chaumont proposed to the publishers of this work the issue of a treatise on Hygiene and Public Health which should contain essays by various authors especially qualified to discuss the several subjects which come within its scope.

The wisdom of adopting this course has been increasingly demonstrated as time has given opportunity for knowledge to grow; for in some degree these subjects have become specialised, and as a result exceptional knowledge and experience of each are required for their proper treatment.

The Editors, in superintending the preparation of these volumes, have been fortunate in obtaining the co-operation of writers whose names are the best guarantee of the value of their contributions.

The work has been divided into different sections, each of which is independent of the others; but, inasmuch as numerous authors have been employed in its elaboration, and one subject is often related to another, it has not always been found possible, without destroying the completeness of an article, to avoid dealing in it with matters also treated by another writer. In a few minor instances the views upon the same subject by different authors have not always been fully in accord.

It has, however, been thought that it would be better in a work consisting of articles to each of which the author's name is appended, to allow of some freedom in this respect, rather than to endeavour to bring occasionally divergent views into harmony, especially when the data to hand do not afford grounds for complete judgment.

The several articles consequently do not necessarily represent the views of the Editors; each author is separately responsible for those he expresses, the work of the Editors being more particularly directed to ensuring a convenient arrangement of the subjects.

In the selection of subjects the Editors have been mainly guided by the requirements of the Medical Officer of Health at the present time, after a lapse of more than forty years since this office was created. The earliest conceptions of the Medical Officer of Health showed that he was expected to be no mere empiricist. So long ago as the year 1848 an instructional minute of the General Board of Health required

that he should make himself familiar with the natural and acquired features of the place to which he was appointed; with the levels, inclinations, soil, wells, and water springs of the district; with its meteorological peculiarities; with the distribution of its buildings and open spaces, and of its burial-grounds; with its drainage; with its industries; with the house accommodation of the poorer classes and their opportunities for personal cleanliness; and with the regulations in force for lodging-houses and slaughtering-places, for the cleansing of the place, and for the removal of domestic refuse. He was also to obtain information as to disease prevalence, and as to the extent of its dependence upon removable causes.

It was held that for the proper performance of his duties he was to be skilled in pathology, because this science implied an exact study of the causes of disease in their relations to the living body. A knowledge of vital statistics was held to be necessary for the purpose of enabling proper comparison to be made which would give evidence of the effect of various conditions on the population. He was to be skilled in chemistry and the use of the microscope for the purpose of judging of the impurities of air, earth, and food, and his chemistry was to help him in the application of deodorising and disinfecting agents. And natural philosophy was to aid him in its relation to ventilation and atmospheric changes, and with reference also to manufacturing processes alleged to be hurtful to health.

The experience of the time which has elapsed since this minute was issued bears witness to the wisdom of its authors. The subject-matter which now comes within the province of the Medical Officer of Health is mainly an amplification of that of which the minute gives account.

With the 'more exact study of the causes of disease' has grown the science of preventive medicine, of which the basis is a knowledge of the natural history of disease. The investigation of the causes of disease has now for a number of years been prosecuted in the laboratory as well as in the field by many capable observers both in this country and abroad.

In this way there has already been established the intimate relation of micro-organisms to communicable maladies, and certainly for each of certain diseases it has been definitely shown that a particulate organism is the cause. Again, it has been learnt that other animals than man may serve as the hosts of these organisms, and hence, in seeking for the source of disease of this sort in the human subject, the inquirer is led to study disease in the lower animals. Man in his domestication of animals, and in his use of their flesh and products as his food, is exposed to invasion by diseases from which they and he alike can suffer.

Coincident with efforts to become acquainted with the ultimate cause of communicable diseases, the study of the natural history of these maladies has been diligently pursued. Fresh facts have been learnt concerning their beginnings and the methods of their dissemina-

tion, of the effects upon their prevalence of the aggregation of children in schools, of the advantages and disadvantages attendant upon the isolation of persons suffering from them in hospitals, and concerning a variety of other circumstances respecting them which, for the purposes of their prevention, it is important should be known.

The part played by earth, air, and water in connection with disease in man is now better understood, and particularly as a result of the work of the last few years. The general notions that filth played an active part as a producer of disease are being replaced by a more precise knowledge of the particular maladies that are encouraged thereby, and of the circumstances under which filth can itself conserve and foster the specific entities which are the essential causes of certain of these affections. Moreover, the physical conditions which give opportunity for these influences to exert a destructive power are becoming more accurately determined, and hence the work of the health authority is ripening into the application of definite knowledge for the preservation of the community.

The ability of populations to protect themselves from preventable disease is necessarily in some degree dependent upon economic considerations. Earlier efforts have been inevitably tentative, and as a result there exists a not unnatural desire on the part of representative bodies to postpone taking a costly procedure until the course which may be best adopted is well defined. Nevertheless, as the result of the efforts of more enterprising communities, there is accumulation of valuable experience in reference to such questions as methods of conservancy, water supply, the arrangements of streets and houses, which are ready to be utilised by the Health Officer in advising the authority he serves.

Although the lessons learned by the investigator are not always immediately applicable for the day by day administration of the Sanitary Authority, nevertheless they provide a basis for further inquiry by those employed in the public service, and indicate the points which they should observe in their examination of the phenomena which are constantly before them. And beyond all question the results hitherto gained give ample guarantee of the value, and indeed of the necessity, of the acquisition of knowledge for guiding communities in their control of individual action.

The coincidence of the enforcement of the public health law and the reduction of the general death-rate, as demonstrated by the valuable records of the statistical department of the State, suffices for the encouragement of sanitary authorities in perseverance in the duties which devolve upon them, and indeed demand from them the removal of conditions which have been found to be in a special sense habitually related to the causation of particular diseases.

As the public mind has become possessed by the consideration that disease is largely preventable, the claim tends to be more fully recognised that the community should possess the right to regulate the action of the individual in the interest of the public health. In

earlier years such a claim was regarded with some distrust and even with dissatisfaction; at the present time, however, the attitude of the public towards health administration is very different, and successive Parliaments have conferred on sanitary authorities additional powers for the control of conditions prejudicial to health, even to the extent of placing under exceptional circumstances a limitation on personal liberty. The English Law of Public Health has, moreover, become the basis of colonial and foreign legislation, and is necessarily subject-matter with which the Health Officer must make himself intimately acquainted.

It has been the desire of the Editors that the several papers which these volumes contain should present for the use of readers a fair account of the knowledge, so far as obtainable, of the subjects of which they treat. These subjects are in the main those which are usually dealt with in similar works, but in the selection of authors it has been thought well not to limit the choice to members of the medical profession. Thus, while air has been treated by the physician, warming and ventilation have been entrusted to the physicist; again, climate has been discussed by the physician, and meteorology has been allotted to the meteorologist; and again, the article on the dwelling has been contributed by members of the architectural profession, while the surgeon has undertaken the discussion of hospital hygiene. In addition to the subjects heretofore contained in works on Hygiene, it has been thought desirable to give equal prominence to some others which have become now of not less concern to the Health Officer. Systematic Physical Education, which has long been neglected in this country, is now receiving more attention, and the need for its recognition as part of every educational system is generally accepted, and hence a section has been devoted to its discussion. A separate section has also been devoted to the discussion of English Sanitary Law. The pathology and etiology of infectious diseases have necessarily, in view of the immense advance lately gained in these subjects, appeared to deserve an especial place in a work which gives account of preventable disease. Accordingly, in order to make this section self-contained, and to obviate the necessity of the reader seeking elsewhere explanation of the matter he is studying, it has been considered necessary that it should give some account of bacteriology and the methods of examination of micro-organisms. Further, with a view to making the account of this class of malady fairly complete, a section has been added on the Natural History and Prevention of Infectious Diseases.

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AIR

Air is a mixture of oxygen and nitrogen with minute traces of other gases: in that collected near the surface of the earth, mineral substances are always present, together with a variable amount of dead and living organised matter.

Statistics prove that impure air is one of the most important of the causes of death which are always present. Density of population favours the spread of organic impurity in the atmosphere, consequent on dirt, overcrowding, and poverty, and this unfortunately is the normal condition of populous and manufacturing towns. The same has been observed with respect to animals, the health of the animals being in direct proportion to the purity of the air they breathe.

The following is the composition of average air:—

Composition of Atmospheric Air.

Oxygen	209·6 per 1000 volumes.
Nitrogen	790·0 ,,
Carbon dioxide	0·4 ,,
Watery vapour	varies with temperature.
Ammonia	trace.
Organic matter, dead or living, organised or unorganised	variable.
Ozone	variable.
Salts of sodium	variable.
Other mineral substances	variable.

The gases which make up atmospheric air do not exist in chemical combination, but form a mechanical mixture. This is proved by the fact that they are not found in the air in the proportion of their combining weights, nor in any multiple of these, the oxygen being the active agent required in all the processes of oxidation (i.e. combustion); the nitrogen a passive agent, taking no part in the processes of respiration and serving the purpose of an innocuous diluting agent.

The air we breathe in large open spaces is liable to very little change in the proportion of its chief constituents; this is due to the diffusion of gases, to the influence of air-currents, and to the reciprocal action of animals and plants upon it, and recent observations have shown only slight differences in its composition in different parts of the earth.

The amount of oxygen in pure mountain air is 209·8 per 1000 volumes, while in the air of towns [1] it may fall as low as 208·7; it is said to be slightly higher in wet weather or immediately after rain than in dry, foggy weather.

The amount of carbon dioxide in normal air ranges from 0·2 to 0·5 per 1000 volumes. Schlagintweit states that it slightly increases up to 11,000 feet in height and then decreases; but this is denied by Tronchet,[2] who declares that the CO_2 diminishes in amount above 3300 feet.

[1] *Air and Rain.* By R. Angus Smith.

[2] Arnould, *Nouveaux Eléments d'Hygiène*, p. 286.

Levy gives, as a mean of his observations at Montsouris, 0·298 per 1000 volumes. In the Dundee experiments Carnelley, Haldane, and Anderson[1] found an average of 0·390 and a range of 0·220 to 0·560, the mean during the day-time being 0·380, and during the night-time 0·410, in open spaces; in close spaces at night the mean was 0·420. In the suburbs the mean was only 0·280, with a range of 0·180 to 0·350, and in the outskirts of Perth a mean of 0·310, with a range of 0·290 to 0·350.

The amount of watery vapour in air varies with the temperature; the higher the temperature the more water can be vaporised; the difference in the amount being often as great as from 1 to 12 grains in a cubic foot of air. It is the most variable constituent of the atmosphere, but forms on an average from 60 to 75 per cent. of the amount necessary for complete saturation.

Ozone.—The nature and action of ozone are not yet quite understood. It is now generally admitted by chemists to be an allotropic form of oxygen and a compound molecule made up of three molecules (O_2O) of oxygen, while antozone is peroxide of hydrogen (Odling).

There is no satisfactory method of testing for ozone; the reaction with ozone paper is imperfect, but certain results have been recorded which are fairly trustworthy. The ozone reaction is absent in impure air, in the interior of large towns, near decaying substances, and in crowded dwellings; there is more reaction in the suburbs of towns than in the centre, more on the tops of mountains than in plains, more near the sea shore than on flat inland surfaces. Ozone is a powerful oxidising agent, oxidising substances which oxygen will not attack; the quantity contained in the atmosphere is very small, probably rarely exceeding, if even reaching, one part in 10,000.

Ammonia is always present in the air, in minute traces, either free or combined: the proportion present is at its minimum in winter, increases in the spring, and is highest in summer. Plant life derives its nitrogen in part from this source.

Organic matter, which ought to be considered as an impurity, is hardly ever absent.

IMPURITIES IN AIR

A variety of substances are continually passing from the surface of the earth into the atmosphere in the condition of gases, vapours, and solid particles; these would accumulate and render the air irrespirable if their effects were not counteracted by the forces of nature which are continually at work in one form or another. Diffusion, dilution by wind, oxidation, and the fall of rain are the chief purifying agents, while the processes going on in the vegetable world diminish the amount of carbon dioxide evolved and keep it within certain limits: gases diffuse and are rapidly diluted and dispersed by winds so as to be rendered innocuous. It is only in the air of enclosed spaces, when the natural processes of purification are arrested, that any great deviation from the normal standard occurs.

SUSPENDED MATTERS IN THE AIR

An immense number of substances pass into the air and may be suspended in the atmosphere. The nature of the suspended matters depends chiefly on the locality and other varying conditions. Air of elevated sparsely inhabited places is almost free from suspended matters, while in low-lying and thickly populated districts they are very abundant, and Pasteur has

[1] *Philosophical Transactions Royal Society*, No. 178 (1887).

shown the immense difference in this respect between the air of glaciers and that of inhabited regions at a slightly lower level.

The suspended matters in the external air are partly mineral, partly organic.

The mineral matters consist largely of silica, peroxide of iron, chalk, clay, soot, chloride of sodium, &c. These are most present in the air in dry weather, rain not only preventing such particles being lifted by the wind, but also washing all suspended matters out of the air and so purifying it.

The organic suspended matters consist principally of grains of pollen, algæ, fragments of hair, wood, straw, stable manure, débris of insects, &c. In Southern Europe and Africa diatoms may be seen, but they are seldom found in this country. Ehrenberg gives the microscopic examination of seventy showers: in addition to particles of sand and oxide of iron he discovered very many different living forms, chiefly rhizopods, tardigrades, and anguillulæ. In larger towns, especially where manufacturing works exist, the air is often loaded with soot and dust of organic origin, which floats in considerable quantities near the surface of the ground. In an analysis of street dust made by Mr. Tichborne[1] in Dublin he showed that the organic matter present varied from 45·2 per cent. in the air of the street to 29·7 per cent. at the top of Nelson's Pillar (134 feet high); the organic matter was chiefly finely ground stable manure: it acted as a ferment and reduced nitrate of potassium to nitrite. In de Chaumont's experiments at St. Mary's Hospital, Paddington, and University College Hospital, the suspended matter collected from the external air included the following substances: epidermis of hay, fragments of pine wood, linen and cotton fibre, epithelium from the mucous surfaces, feathers, charred vegetable particles, and mineral matter. When the air is motionless these suspended matters, as a rule, subside, though some are so light as to float in rarefied air, and Tyndall has shown that if burnt a little bluish mist arises from the combustion, indicating that those consumed are, from their destructible nature, of organic origin.

The presence of bacteria in external air has recently been the subject of close investigation. They flourish whenever they meet with sufficient moisture, nutritive material, and a suitable temperature (above 60° Fahr.); they appear to pass into air from colonies lying on the surface of the earth which are broken up and afterwards scattered by wind. Once passing into the air they float about in the atmospheric currents; a few adhere to the grosser particles of dust and fall in quiescent air, while others are not deposited even in air which is at rest. Their numbers depend on local conditions, as when there is nutriment for a plentiful development on the surface of the earth and where the superficial colonies are broken up; this is partly the reason that bacteria are not found in high mountains, over desert plains, or on the sea. This is well shown by the following examples given by Miquel:—

	Microbes per cubic metre of air
High Mountains	1
Mid-Atlantic Ocean	6
Hôtel Dieu (Paris)	79,000

It is not known how far bacteria can be carried by wind, but as dust can be conveyed to an almost indefinite distance (as shown by the eruption of Krakatoa, which is supposed to have scattered fine dust over the greater portion of the globe) it is not unnatural to presume that bacteria also may be carried over considerable areas. Fischer, however, states that he found no microbes beyond 120 miles from land.

[1] *Chemical News*, 1871.

Of the physical conditions of the air which influence the number of bacteria, dry winds and, in towns especially, drought lasting for some time, favour their increase; during this latter period many varieties of bacteria, and even pathogenic bacteria, pass into the air. The amount of aqueous vapour present also influences the number of bacteria, as the condensation of vapour leads to the sinking of the particles of dust to which the bacteria adhere, while rain washes the air and brings back to the earth the greater number of these organisms. In external air the pathogenic bacteria form only an infinitesimal part compared with the saprophytes, and all recent experience goes to show that the danger from the entrance of pathogenic bacteria from external air into wounds is extremely small, and that this is occasioned far more frequently by other causes.

Miquel in his experiments found the air of Montsouris to contain on an average (mean of six years' observations) 450 microbes per cubic metre of air, but these were chiefly in the form of spores. In the streets of Paris the average number to a cubic metre of air was 900.

In the Dundee experiments Carnelley, Haldane, and Anderson found the average number of organisms to be less than one per litre, in the proportion of three bacteria to one mould.

The present evidence goes to prove that in the open air the dilution of bacteria is so great, and the number of pathogenic bacteria so very small, that no danger is to be apprehended from them unless they originate from local sources of impurity.

DISEASES PRODUCED BY IMPURITIES IN AIR

For many years attention has been directed to the great amount of respiratory disease caused by dust inhaled into the lungs by those who worked at certain trades, and a large number of facts relating to this subject have been collected: acute pneumonia, bronchitis, and non-tubercular phthisis are produced, the severity of these diseases depending chiefly on the amount of dust and on its physical conditions with regard to angularity, roughness, or smoothness of its particles.

The suspended matter in the air may be of animal, vegetable, or mineral origin, but it is the latter chiefly that gives rise to the most severe results, as is seen in the case of miners of all kinds. Dr. Ogle[1] has shown the excessive mortality produced among Cornish miners from phthisis and other respiratory diseases. The 'comparative mortality figure' in 1880—82 was 1839, that of all males in England and Wales being 1000, and Cornish males 887; from phthisis and other respiratory diseases the comparative mortality amongst Cornish miners was 1148, while amongst coal miners generally throughout England and Wales these diseases gave only 328. It would appear that this excessive mortality is due to some condition peculiar to tin mining (which is almost exclusively carried on in Cornwall), where the dust disengaged is more irritant and ventilation less perfect than in other mines. Owing to improvements in the system of ventilation adopted in mines (especially those in South Staffordshire and South Wales) during the last few years, there has been a great decrease in lung affections, although chronic bronchitis, asthmatical breathing, and vicarious emphysema still prevail. The workers in lead mines suffer from lead poisoning and bronchitis, due to inhalation of dust, and at Reeth, in Yorkshire, where one-half the male

[1] *Forty-fifth Report of the Registrar-General.*

population work in lead mines, the deaths from respiratory diseases are double those of the agricultural population. In copper mines the dust of copper ore is credited with producing severe gastric and intestinal irritation, characteristic of copper poisoning. Among this class of workmen there is a peculiar browning of the skin, wasting, dyspnœa, cough, and coloured expectoration. The manufacture of pottery, in which a large quantity of mineral dust is thrown into the air, is productive of much disease: the clay used consists of disintegrated granite mixed with powdered flint, while in some cases felspar is added. The clouds of dust given off in the various processes are exceedingly irritating to the lung structure, even more so than in coal mining; partial condensation of the lung substance, due to the slow inflammatory action caused by the inhalation of these irritating particles, follows, and produces the condition known as 'potter's lung.' Emphysema is common, its general features being that those affected resemble asthmatical subjects; the disease is frequently complicated with phthisis.

Steel grinders suffer most severely from the entrance of particles of dust into their lungs, but the further development of the process of wet grinding has of late years somewhat lessened this evil, and improved ventilation by means of fans has also effected a considerable diminution in the numbers attacked and in the mortality. In the needle trade, which is altogether dry grinding, extraction tubes are attached to each grindstone, and the greater part of the dust is collected and drawn from the workman; notwithstanding this, lung affections are extremely prevalent, while the mortality from tubercular phthisis and scrofula is excessive.

The inhalation of dust of vegetable origin produces much the same train of symptoms. In the sorting, scutching, and carding of cotton the introduction of closed machinery has done much to mitigate the evils arising in the process of manufacture. In the spinning and sizing of cotton much dust is given off. In flax factories a very irritant dust is produced, known among the workers as 'pounce'; those exposed to it suffer from severe dyspnœa, paroxysmal in character, and the dust inhaled is exceedingly difficult to get rid of by expectoration; it produces a whole train of nervous symptoms. Women suffer most severely, as they form the majority of employés in the mills. The dust arising from the manufacture of silk is less irritating; it is difficult to say whether, apart from other conditions present, the amount of dust is as destructive as in other trades.

In the manufacture of 'shoddy' a large quantity of irritant dust escapes from the machines, producing a febrile condition characterised by headache, sickness, difficulty of breathing, cough, and expectoration. Stonecutters suffer severely from the inhalation of stony particles, which set up slow inflammation in the lungs; those working on hard and flinty stones are most affected. It is said that men cannot continue working at this class of stone for more than eight years, although during the first three or four years they suffer very little from it. The makers of Portland cement inhale a considerable quantity of finely ground cement, when transferring it into sacks; it prevents their continuing at the same work for a number of days in succession; they frequently expectorate little masses of cement.

Electroplate and Britannia metal workers suffer from the large quantity of dust evolved in the polishing and cleaning with lime, and from minute particles of the metal which become detached. Workers of mother-of-pearl and ivory also suffer to a considerable extent, the fine dust giving rise to lung irritation, cough, and hæmoptysis.

The mortality among workers in certain dust-producing trades from phthisis and respiratory disease, as compared with the mortality in England

and Wales generally, is shown in the following table, deaths from all causes in males being taken as 1000 :—

Comparative Mortality.

	Phthisis.	Respiratory Diseases.
All males (England and Wales)	220	182
Earthenware manufacturers	473	645
File makers	433	350
Miners, Cornwall	690	458
Printers	461	166

The makers of matches formerly suffered from necrosis of the lower jaw, if there was any exposed part on which the fumes of phosphorus could act. The substitution of red or amorphous phosphorus has obviated this danger, as this does not vaporise, and is therefore harmless.

In some trades the fumes of metals as well as particles of metallic dust pass into the air. Plumbers inhale volatilised oxide of lead, which rises during the process of casting, and also from the fumes produced in burning off old paint; formerly a large mortality followed the grinding of white lead, but since the moist process has been substituted less harm results.

Brassfounders are subject to bronchitis and asthma, and also 'brassfounder's ague,' which is said to be produced by the fumes of zinc oxide; the symptoms are febrile, attended with nervous depression, which obliges them to cease work for a few days. Coppersmiths are occasionally affected in the same way, from inhaling the fumes of the partly volatilised metal. In the manufacture of tobacco some dust is given off, which produces for a short time, in those newly employed at the work, nausea, giddiness, and irritation to the eyes, but they soon become inured to their work.

Workers in mercury are subject to mercurialism, and formerly salivation and palsy were common, but this has greatly diminished since electricity has rendered gilding with the aid of mercury obsolete, and the manufacture of mirrors from nitrate of silver has practically abolished mercurial affections.

Arsenic in the form of Scheele's or emerald green is the cause of great suffering to workmen employed in the making of artificial flowers or wall papers, as well as those who occupy rooms so papered. Such persons suffer from painful rashes, sore eyes, sickness of stomach, and generally the symptoms of arsenical poisoning.

Gas makers frequently suffer from the noxious effluvia given off by the refuse lime used in the making and purifying of gas.

In addition to inorganic substances and metals there are organised and living bodies which are suspended in the air, such as pollen of flowers, algæ, fungi, and bacteria. Hay fever is produced in susceptible persons by the pollen of flowers (especially *Anthoxanthum odoratum*); the spores of fungi are known to cause diseases of the skin in man, and they may certainly be regarded as the medium by which such diseases as tinea and favus are spread.

Dr. Salisbury,[1] of Newark, Ohio (U.S.A.), has demonstrated his ability to produce a disease indistinguishable from measles by inoculations of the fungi from mouldy straw, but his experiments have not been confirmed. Measles is also said to have been produced by the fungi growing on linseed meal.[2] Hallier, of Jena, also favours the view that fungi spores are the cause of specific diseases. That bacteria of various kinds produce disease appears

[1] *American Journal of Medical Sciences.*

[2] *Dublin Journal of Medical Science*, vol. xxxv. 1863, p. 60.

now to be finally settled and accepted. Many have been cultivated in pure cultures, their life-history studied, and particular species identified, and the disease produced by inoculation. As examples may be mentioned *B. anthracis* in woolsorter's disease, *B. tuberculosis* in phthisis, *B. lepræ* in leprosy, and *B. Obermeieri* in relapsing fever.

Certain diseases appear to be more associated with impure air than others; whether the contagia are capable of growth and multiplication in the air is uncertain, but that they can retain their vitality for a long time there can be no doubt: the poisons of scarlet fever, smallpox, and enteric fever retain their powers of infection for weeks, and are capable of exciting disease in any person susceptible to their influence. The specific poisons of various diseases differ in the way in which they are destroyed or rendered innocuous by dilution; the poison of typhus fever is very volatile, rapidly diffuses, and is perhaps oxidised and got rid of by free ventilation; so that an interval of a few feet gives under such circumstances sufficient protection, while exactly opposite conditions appear to be the case with the poisons of smallpox and scarlet fever. The poisons of cholera and diphtheria also are believed to be borne some distance by wind, and malaria has been known to be conveyed thus for several hundred yards without its infective power being lessened.

GASEOUS MATTERS IN THE AIR

Carbon dioxide.—Normal air contains from 3 to 6 parts of carbon dioxide in 10,000; the amount increases during the night and diminishes after sunrise: it is less over large tracts of water than over land, and is more abundant in crowded cities than in the open country. The addition of 10 to 15 per cent. of CO_2 to air would render it poisonous, although larger quantities are said to have been inhaled without injury. Dr. Taylor states that in mines in Cornwall where the air contains not more than 2 per cent. the miners suffer considerably, but other circumstances than the CO_2 have here to be taken into account. In Dr. Angus Smith's experiments one per cent. of this gas in air from which the organic matter of respiration had been eliminated produced slowness of the heart's action with quickening of the respirations; it is, however, uncertain what would be the effects produced by breathing continuously an atmosphere containing 1 or 1·5 per cent. of this gas; when it reaches this amount organic matters and possibly other gases are present and the quantity of oxygen is also lessened.

Carbon monoxide.—The poisonous action of carbon monoxide renders a very small quantity of this gas dangerous. Experiments tend to show that when it is absorbed by the blood it combines with the hæmoglobin; it appears to act as a pure narcotic poison.

The large quantity of CO (as much as 34 per cent.) in 'water gas' renders its employment dangerous as an illuminant, the gas being inodorous and unirritating; poisonous effects are produced if it is inhaled. To avoid this risk it has been suggested to 'odorise' it, and mercaptan and pyridine have been employed for that purpose.

Roburite, a mixture of dinitrobenzene, chloronitrobenzene, and ammonium nitrate, has been lately used as an explosive in mines. The fumes resulting from the use of this compound give rise to blueness of the lips, headache, some dyspnœa and loss of muscular power, drowsiness, and occasionally vertigo followed by vomiting; carbon monoxide is produced by its explosion.[1]

[1] *British Medical Journal*, June 15, 1889.

Sicherheit explosive causes somewhat similar symptoms, and especially marked cyanosis, in those employed in its manufacture.

Hydrogen sulphide.—The effects produced by the inhalation of this gas vary according to the degree of its dilution. If present in somewhat large quantities, nausea, headache, irregular action of the heart, and even convulsions follow, but in dilute doses it produces only low febrile symptoms resembling typhoid fever. The bad effects caused by the inhalation of this gas are mostly to be traced to the opening of old drains and cesspits. Dr. Letheby considers one per cent. in the air would be destructive to human life. Hirt has no doubt that the inhalation of small quantities of this gas produces chronic poisoning in those exposed to the fumes.

Disulphide of carbon.—The extensive use of carbon disulphide in india-rubber manufactories produces chronic poisoning, due to the vapours given off. The symptoms are headache, giddiness, and excitement of the nervous system, and these may be followed by insanity. The vapour is exceedingly offensive, nauseous, and very inflammable.

Hydrochloric acid vapours when inhaled are extremely irritating to the lungs, causing bronchitis, pneumonia, and ulceration of the trachea. This and other acids are used in some of the processes for the making of steel; unless protected, the eyes also suffer.

Ammoniacal vapours are given out in some manufactures; but they have not been noticed to have any injurious effect on the health of operatives, except occasionally producing inflammation of the conjunctiva.

Organic effluvia.—Effluvia are produced in nearly all the trades in which animal products are concerned, such as in tanning, leather dressing, glue making, soap works, slaughter-houses, gut scraping; there are also the effluvia arising from stables, cow-sheds, pig-styes, &c.; although there is no evidence to show that persons actually employed in these trades suffer in health, there is a well-grounded belief that the general health of those living in the immediate neighbourhood is lowered, and that diseases in their case are apt to assume a more severe type. Some of those exposed to these emanations suffer at first from loss of appetite, nausea, vomiting, and diarrhœa, while residents in the vicinity appear more frequently affected than those actually employed in the trade.

Excessive humidity.—Excessive moisture, which is nearly always associated with high temperature, is found in weaving sheds and also in certain branches of the silk trade. Steam is injected into the sheds in order to communicate the necessary amount of humidity without which the warp, which is sized with china clay, could not be woven; in consequence the weavers work in damp clothes and fill their lungs with moisture; they are very liable to bronchitis, due to chill on leaving the overheated factory, and lung diseases cause a large mortality among them. Hat makers, who work under somewhat similar conditions, suffer in the same way.

Effect of air rendered impure by respiration.—Air rendered impure by respiration may cause heaviness, headache, and nausea, the poisonous agent present being the organic matter: there is also generally a deficiency of oxygen. When the air is rendered very impure it is rapidly fatal, as in the cases of the Black Hole at Calcutta and of the steamer 'Londonderry.' This vessel left Sligo for Liverpool, and stormy weather coming on the captain forced 200 steerage passengers into their cabin, which measured 18 feet by 11 feet and 7 feet high. The hatches were battened down and covered with tarpaulin: when the cabin was opened seventy-two persons were found dead and several expiring. Persons whose occupation obliges them to continuously breathe a vitiated atmosphere become pale and anæmic, and suffer from loss

of appetite, headache, &c. Such persons are more prone to phthisis and diseases of the respiratory organs than those whose occupation admits of their passing their time in well-ventilated rooms or in the open air. Sedentary habits, want of exercise, improper food, added to the influence of impure air, are extremely productive of phthisis; but it has been clearly shown that breathing air rendered impure by respiration is more potent than any other condition which predisposes to this disease. A good example of this may be found in the army, especially in foreign stations, where an increase of the cubic space allowed to each man and the means adopted to remove foul air have caused a notable decline in the cases of phthisis, and the only circumstance which has brought about this change at these places is the condition of the air. The same results are seen on service in the field, where the rudest shelter is better than overcrowded barracks. In the Afghan War pneumonia was very prevalent and fatal in the overcrowded barracks, while there was not a single case among those in tents; distributing the men in tents had the effect of at once stopping the disease.

Air rendered impure by exhalations from the sick is well known to be injurious. In military hospitals hospital gangrene and erysipelas were among the most prevalent diseases in former wars; now they are almost unknown, and the occurrence of a case is considered evidence of neglect. The organic emanations being greater from the sick than from those in health and the metamorphosis of tissue more active, pure air is essentially necessary to facilitate recovery.

The effect of breathing air into which the products of gas combustion have passed is to be seen in workmen who are obliged from the darkness of their shops to burn gas during a large part of the day. Bronchial affections are common, and in proportion to the amount of contamination of the air they suffer from headache, drowsiness, and oppression. Another example of the injurious effects produced by gas may be inferred from the fact that in the Savings Bank Department in Queen Victoria Street, where 1200 persons are employed, the introduction of the electric light in place of gas has so far reduced the absences from illness that the extra labour gained has paid for the electric light.

Air polluted by sewage emanations, whether arising from sewers, drains, or cesspits, is capable of causing vomiting, diarrhœa, and great prostration. When inhaled largely diluted it produces headache and a general low state of health; children appear to be more susceptible to its influence than grown-up people; they become languid and may suffer from diarrhœa and sore throat. The special diseases that have been more particularly noticed in connection with sewer air are enteric fever, diarrhœa, and diphtheria. As regards enteric fever there is doubtless a distinct causal connection between the inhalation of sewer air and the occurrence of the disease. The persistent attacks of enteric fever, which formerly occurred at Eastney Barracks, were due to sewer air being forced back by the tide, no traps or ventilating openings being supplied; since this was remedied and ventilation carried out no case of fever has occurred.

On the other hand enteric fever does not appear to be more common among sewer men than others, and those workmen employed on sewage works do not furnish an unusual number of cases.

If we admit the extreme danger which arises from the inhalation of sewer air, knowing that the specific cause lies in the intestinal discharges which naturally pass into the sewers, every procurable means should be adopted to prevent the entrance of sewer gas into houses, although the subject presents difficulties which cannot always be explained.

With regard to diarrhœa a worse type generally prevails in badly drained than in well-drained districts: this disease, though intimately associated with soil temperature, is favoured by sewer emanations. In London a heavy fall of rain has checked its spread—possibly by sealing traps which a previous drought had caused to become dry, and thus preventing sewer gas from escaping.

The spread of diphtheria has been ascribed to the pollution of air by emanations from sewers, and certainly there is a close connection between the sanitary condition of a district and the occurrence of this disease; the inhabitants of houses into which sewer gas enters are especial sufferers. Reference may be made to outbreaks recently recorded by the late Mr. Spear, of the Local Government Board. There is no evidence to prove that the emanations from well-managed sewage farms are injurious to health. Dr. Carpenter has shown that the sewage farm at Beddington can be carried on without risk to persons in the vicinity, and where exhalations have been said to produce disease the fault has been with the improper treatment of the sewage and not with the principle.

The fouling of streams and rivers does not furnish such clear evidence; though the cases recorded among residents in houses on the quays in Dublin or in the worst districts in Lancashire show no great excess of disease, there is nevertheless considerable proof that inhalation of offensive odours is often productive of diarrhœa. Probably the results much depend on the dilution of the sewage matter. When very dilute there appears to be little danger from evaporation.

The air of graveyards contains an excess of CO_2, and when they are densely crowded, and deep burial is not insisted on, there are also found fœtid organic vapours, sulphuretted hydrogen, and ammonium sulphide, which increase the sickness and mortality among those living in the immediate vicinity; any disease occurring in such a situation assumes a virulent and unfavourable type. But under modern regulations there appears to be no danger from this cause. Care must be taken, however, that no contamination reaches the water supply, especially that used for drinking purposes. In India it is well known that cholera assumes a more severe and fatal type in stations where barracks are built in close proximity to the sites of old burial-grounds. A remarkable case occurred in Yorkshire [1] a few years ago, in connection with a churchyard, where a number of persons who died from scarlet fever had been buried thirty years previously. A part of the churchyard was closed, but was afterwards included in the garden of the Rector, who had it dug up, whereupon scarlet fever broke out in his family and spread to the neighbouring houses. Gravediggers appear to suffer no injurious effects from their calling; no excess of mortality among them is recorded.

The effluvia arising from decomposing carcases produce diarrhœa, dysentery, and a low febrile condition; this has been especially noticed in military campaigns, where it is often impossible to bury horses that have died or been killed in action. In well-managed knackeries the men do not appear to suffer, although it is said that glanders and malignant pustule have been caught in this way.

The air of brickfields, especially those in which the bricks are burnt in a quadrangular pile and not in kilns, is very offensive; sulphuretted hydrogen, carbon dioxide, carbon monoxide, and fœtid organic vapours with thick smoke are given off, particularly when house refuse is used in the manufacture. The emanations are acid and destroy vegetation; when inhaled they are very irritant. In burning cement the same disagreeable effects are produced,

[1] *Sanitary Journal*, December 17, 1888.

the gases given off being chiefly CO_2 and SH_2, also volatile cyanides in some instances, which are very poisonous.

The air of marshes has given rise to malarial fevers, the specific poison being rapidly carried by the wind to a considerable distance; it is more intense near the ground than a few feet above it, and is easily stopped by mechanical barriers. This disease is now seldom seen in England, but is very prevalent in the tropics during the rainy season.

ON WHAT BASES ARE WE TO CALCULATE THE AMOUNT OF FRESH AIR REQUIRED?

In order to calculate the amount of fresh air required to maintain an inhabited room or enclosed space in a well-ventilated condition, it is necessary (1) to know the nature and amount of the impurities that are added to the air by reason of the presence of human beings; (2) to have some means of determining the presence of such impurities, and, if present, their amount; (3) to fix on some standard of ventilation, or limit in the amount of impurities which must not be exceeded in an air-space, if such space is to be kept in a proper and wholesome condition.

It will be convenient to consider, first of all, the case of ordinary dwellings occupied by healthy persons, and, subsequently, certain special conditions, as those of schools, factories, and hospitals.

1. The impurities present in an air-space that are due to the fact of its being inhabited fall under the three heads of (A) those that are derived from the inhabitants themselves; (B) those that are produced by the artificial lighting or heating of the chamber; and (C) those derived from the walls, furniture, &c. of the room.

A. The first category may further be considered under the two divisions of the impurities due to (1) the *breath* and (2) the *perspiration*.

(1) *Impurities due to the Breath*

The changes that take place in air that has been respired are the following: (*a*) the temperature is raised; (*b*) consequently the volume is increased, but if the inspired and expired air be measured at the same temperature and pressure there is a diminution in volume; (*c*) there is an increase in the watery vapour; (*d*) also an increase in the carbon dioxide; (*e*) nitrogen and (*f*) ammonia; (*g*) the oxygen is diminished; (*h*) there is an addition to the air of hydrogen; (*i*) marsh gas; and (*k*) organic matter. Of these several alterations in the composition of the air the increase in the carbon dioxide and watery vapour, and the addition of organic matter, are the most important from a hygienic point of view.

The composition of expired air by volume may be stated as—

	Per cent.		
Oxygen	16·033	Hydrogen	trace
Nitrogen	79·557	Methyl hydride (CH_4)	trace
Carbon dioxide (CO_2)	4·380	Aqueous vapour	nearly to saturation
Ammonia (NH_3)	traces		

(i) *Carbon Dioxide*

The amount of CO_2 exhaled in respiration has been investigated by numerous observers, the quantity estimated varying from 31·5 grammes (Ranke) to 37·5 grammes (Vierordt), equalling 0·56 to 0·67 cubic foot, every hour. There are very many influences at work to cause varia-

tion, and the methods of estimation and apparatus required are delicate and complicated; the determination, therefore, is a matter of some difficulty. The observations of Pettenkofer may be taken as being exceedingly accurate and trustworthy. He found that a man aged twenty-eight years, weighing 132 lb., evolved hourly in complete repose during the night 0·56 cubic foot, in gentle exertion during the day 0·78 cubic foot, in hard work during the day 1·52 cubic foot. These figures give in round numbers respectively—

In complete repose during the night .	·004 cubic foot CO_2 per lb. of body-weight		
In gentle exertion during the day .	·006	„	„
In hard work during the day . .	·012	„	„

Taking now the average weight of adult males as 150 lb., of adult females as 100 lb., and of children as 75 lb., and again using round numbers, these figures give the following data:—

Average hourly Excretion of CO_2 by Lungs, in cubic feet

—	In repose	In gentle exertion	In hard work
Adult males . .	·6	·90	1·8
Adult females .	·4	·60	1·2
Children . .	·3	·45	0·9

The influences that modify the excretion of CO_2 are chiefly the following: (1) *Age.*—The amount is increased up to about thirty years; it remains stationary from thirty to forty-five; after forty-five years it diminishes. (2) *Sex.*—After eight years males give off considerably more than females (according to Andral and Gavarret this increase is about one-third). (3) *Development.*—More CO_2 is given off by the vigorous and robust than by the slender, this increase being more proportionate to the muscular development than to mere size and weight of the body. (4) *Sleep.*—Less CO_2 is evolved during sleep than when lying awake and at rest. (5) *Food and fasting.*—Abstinence diminishes, and the taking of food increases, the evolution of CO_2, the amount of increase varying with the nature of the food. (6) *Muscular exertion* greatly increases the CO_2 given off. (7) The *temperature* of the surrounding air, (8) the *time of day*, and (9) the *season* of year all exercise an influence, the excretion being *increased* by cold, about the middle of the day, and in the spring; and *decreased* by heat, about midnight, and in the autumn.

It is evidently, therefore, a matter of great difficulty to determine the amount of carbon dioxide habitually given off by an average population, on account of these numerous sources of modification; and any attempt at stating a normal or standard amount must be accepted as admitting of variation within very wide limits. In repose 'for a mixed community a general average of ·6 cubic foot per hour may be adopted' (Parkes and de Chaumont); and it should be borne in mind that (1) for muscular adult males a higher figure, ·7 or ·72, should be taken; and (2) that children, although evolving a less amount absolutely than adults, give off relatively, in proportion to their body-weight, nearly twice as much.

(ii) *Aqueous Vapour*

Whatever be the hygrometric state of the atmosphere, the expired air is nearly saturated with moisture. The absolute amount thus added to the atmosphere varies with (1) the temperature of the expired air and (2) the quantity of watery vapour already existing in the air before it was respired. The temperature of expired air varies only within narrow limits; it is usually

higher than that of the surrounding atmosphere, but may be lower; it is slightly below the blood temperature, being about 93° F. to 97° F. According to Pettenkofer and Voit, at a temperature of 59° F., and the relative humidity of the air being 75 per cent. of saturation, an adult gives to the air 10·19 oz. (286 grammes) of watery vapour in twenty-four hours. Other observers estimate the amount as from 200 to 300 grammes (about 7 to 11 oz.); according to Valentin it is as much as 640 grammes (22·5 oz.)

(iii) *Organic Matter*

The nature of the organic matter given off by the lungs has not been precisely determined: it is odorous and putrescible; it decolorises solution of permanganate of potash, and is therefore oxidisable; it also yields ammonia, and is therefore nitrogenous. It is doubtless of a mixed composition, molecular rather than gaseous; and, in addition to substances derived from the lungs, the breath contains particles of epithelium and fatty matters from the mouth and pharynx, and in some cases organic effluvia from the stomach.

Neither has the amount of this complex organic matter been exactly estimated. Carnelley, Haldane, and Anderson made some careful experiments (too few, however, to warrant a general deduction), in which the excess of oxidisable matter in the expired air over that present in the room was found to vary from 1·7 to 13·6, giving an average for one observer of 7·6 and for another 8·3. These figures are volumes of oxygen required to oxidise the oxidisable matter per million volumes of air. The amount is, therefore, by no means constant, and the range of variation is so wide that the averages are not of much value.

(2) *Impurities due to Perspiration*

The matters derived from the cutaneous secretion are both organic and inorganic: the chief are water, sodium chloride, and other inorganic salts in small quantity, various fatty acids, neutral salts, and ammonia (urea); in addition particles of epidermis constantly become detached and float off into the surrounding atmosphere. The quantity of perspiration thus given off is large, but very variable: about 2 lb. (or 900 grammes) of fluid during the twenty-four hours (Seguin) may be taken as an average, containing 1·8 per cent. of solids, of which 1·2 per cent. are organic substances.

B. Impurities due to Combustion

(1) The products of the combustion of coal are carbon, carbon dioxide and monoxide, sulphur, sulphur dioxide and sulphuric acid, ammonium compounds, and water. Wood gives rise to carbon dioxide, carbon monoxide, and water. As these substances commonly pass out into the outer air, they do not require further mention in this place.

(2) The substances resulting from the combustion of coal gas, oil, and candles are usually diffused more or less through dwelling rooms, although they can, and should, be carried off by suitable means, and the air thereby freed from a very considerable amount of impurity. The chief products of the combustion of average coal gas are nitrogen (67 per cent.), water (16 per cent.), carbon dioxide (7 per cent.), carbon monoxide, if the combustion be imperfect (5 or 6 per cent.), sulphurous acid, and ammonia. One cubic foot of gas will unite with from about 1 to $1\frac{2}{3}$ cubic foot of oxygen, according to its quality, requiring, therefore, from about 5 to 8 cubic feet of air, and producing on an average about 2 cubic feet of carbon dioxide. An ordinary gas burner burns between 3 and 5 feet per hour.

An ordinary oil lamp burns about 150 grains of oil hourly, consuming the oxygen of rather more than 3 cubic feet of air, and producing a little more than half a cubic foot of carbon dioxide; 1 lb. of oil requires about 150 cubic feet of air for complete combustion.

A candle burning 320 grains per hour produces about ·4 cubic foot of carbon dioxide in that time (Erismann).

C. Impurities derived from the Walls, Floors, &c.

In addition to the matters already mentioned, the air of inhabited places contains solid particles, not derivable from either of the sources that have just been considered. Under the name of *dust* may be included mineral particles, vegetable and animal *débris*, and dead matter blown in from the outside, or derived from the surfaces of floors, walls, furniture, &c. In ordinary dwellings this dust is, unless in extreme amount, hygienically of little consequence. But either attached to these inert particles or floating freely are great numbers of living micro-organisms, which, though as a rule harmless to the healthy inmate, may under certain circumstances possess the greatest significance. Carnelley, Haldane, and Anderson have shown that the micro-organisms do not come, to any large extent, from the persons present in the room, neither from the lungs nor from the skin; they must therefore come from the room itself. They are found in greatest number in houses that are old, overcrowded, and dirty. When the air is at rest they rapidly fall to the ground, being again dispersed throughout the room when the air is disturbed, particularly when much dust is raised. These minute organisms belong to the groups of moulds (*Hyphomycetes*), yeasts (*Saccharomycetes*), and bacteria (*Schizomycetes*), the latter being much the most numerous.

2. From the above brief summary it is seen that the air of inhabited rooms or confined spaces is rendered impure by the addition to it of solid, liquid, and gaseous matters, both inorganic and organic, dead and living, some derived from the occupants, some from the means used for warming and lighting, some from the rooms themselves. The question has now to be considered, How can the presence of these impurities be detected and their amount estimated?

The means at our disposal to attain these objects are (1) the use of the senses; (2) physical and (3) chemical methods, and (4) examination by the microscope, with which may be included cultivation methods for the detection and enumeration of micro-organisms.

The sense of smell detects an excess of organic matter in an air-space, as evidenced by the closeness or offensive odour of the air; hygrometers, or the wet and dry bulb thermometer, show the amount of watery vapour present. The carbon dioxide can be readily estimated by shaking up known quantities of lime or baryta water and air and comparing the alkalinity of the liquid before and after the operation. The number of micro-organisms present and their nature can be estimated by aspirating a known quantity of air through a suitable apparatus, and preparing cultivations in nutrient gelatine.

These and other methods are described subsequently in the section on the Examination of Air.

It is universally agreed that the organic matter given off by the lungs and skin is the most noxious of all the impurities present in the air of an inhabited space, but, unfortunately, the means for the exact determination of its amount are both imperfect and difficult of application. On the other hand the estimation of the amount of carbon dioxide can be accomplished

with great ease and very fair accuracy. From the numerous experiments in barracks and hospitals conducted by several observers it appears that the oxidisable matter present in air (probably organic), as shown by the amount of potassium permanganate deoxidised, is generally in proportion to the amount of carbon dioxide present due to respiration. The late Dr. de Chaumont, from a large series of observations, proved that the amount of organic impurity present, as shown by the sense of smell carefully employed, increased *pari passu* with the carbon dioxide of respiration, and he deduced certain general rules from this coincident increase. Carnelley, Haldane, and Anderson do not appear to have found so close a connection between the organic matter and the carbon dioxide, and none at all between the carbon dioxide and the number of micro-organisms. For the present, however, de Chaumont's researches give ample justification for the belief that a comparative estimate of the organic purity or impurity of an air-space can be safely made from a determination of the amount of CO_2 present, making allowance for the quantity of CO_2 in the external air.[1]

3. From what has been said in the preceding paragraphs it may be stated: (1) that the chief impurity in an inhabited air-space is the organic matter evolved in respiration and perspiration; (2) that the amount of this present may be estimated relatively by determining the amount of carbon dioxide present; (3) that the amount of carbon dioxide evolved by individuals can be calculated, not exactly, but with a considerable degree of accuracy; therefore (4) the condition of the air-space of known size tenanted by any number of individuals can be calculated, as regards the quantity of CO_2, at the end of one or more hours; and therefore *relatively* its condition as regards organic impurity; and (5) if a standard amount of CO_2 be fixed on, a limit which should not be exceeded, we may ascertain by calculation the quantity of fresh air that must be supplied in order to restrain the CO_2 within these bounds, and therefore *relatively* prevent the organic impurity from exceeding a safe and wholesome limit.

This standard, or limit, has been fixed by Roth and Lex, and by de Chaumont, as 0·6 per 1000 volumes; by Pettenkofer and by Carnelley, Haldane and Anderson, as 1 per 1000 volumes; by all observers the amount present normally in the atmosphere has been taken as 0·4; therefore the excess over this natural quantity should not be more than 0·2 or 0·6 per 1000 volumes respectively. Morin and Ranke advocated the supply of fresh air in such proportions that the excess of CO_2 due to impurity from respiration should not exceed 0·33 per 1000 volumes.

The observations of de Chaumont have been generally accepted, and for the reasons already stated they may be received with confidence. He took as the standard 'the point at which there is no sensible difference between the air of an inhabited space and the external air,' as determined by the sense of smell. This standard may not be easy to attain in every case, but it is better to have a high standard at any rate to aim at. As perfect purity of air in a confined space is out of the question, one must be content with something short of this, but as a theoretical standard the condition should be such that no unpleasant smell or closeness should be appreciable. The temperature and the relative degree of humidity have an influence on the readiness with which smell of organic impurity is perceived; they also them-

[1] A reference to de Chaumont's papers in the *Proceedings of the Royal Society* for 1875, No. 158, and 1876, No. 171, will show the extreme care taken in drawing conclusions from the different series of observations, and a mathematical proof of the close approximation to truth of these conclusions.

selves give indications as to the efficiency of ventilation or the reverse. From de Chaumont's observations, 63° F. and 73 per cent. of humidity may be taken approximately as standards.

Carnelley, Haldane, and Anderson, as just mentioned, have fixed on a lower standard of purity, that is, they propose a higher limit of CO_2, viz. 0·6 volume per 1000 above that in the external air. They also propose 2 volumes per million of oxygen required for oxidation as a standard for the 'organic matter' (or rather the 'total oxidisable matter.' See ANALYSIS OF AIR, p. 23). The number of micro-organisms present should not exceed 20 per litre, and the ratio of bacteria to moulds should not exceed 30 to 1.

Some such standards being agreed upon, it becomes now a matter for calculation to ascertain the quantity of fresh air that must be supplied in order to maintain a space in a well-ventilated condition.

HOW MUCH FRESH AIR IS REQUIRED TO KEEP AN INHABITED AIR-SPACE HEALTHY?

1. If e = amount of CO_2 exhaled per head per hour in cubic feet,
r = admissible limit of CO_2, due to respiratory impurity, stated per cubic foot,
d = delivery of fresh air required in cubic feet per head per hour,

then $$\frac{e}{r} = d.$$

Taking ·6 cubic foot as the average amount of CO_2 exhaled in repose, and ·2 per 1000 as the limit of respiratory impurity, that is ·0002 cubic foot,

$$\frac{\cdot 6}{\cdot 0002} = 3000 = \text{delivery of fresh air required per head per hour.}$$

In this formula if r be ratio per 1000 instead of per cubic foot, then d will be in thousands of cubic feet, thus:

$$\frac{\cdot 6}{\cdot 2} = 3 \text{ thousand cubic feet.}$$

2. If r = admissible limit of respiratory impurity,
r_1 = respiratory impurity, stated in ratio per 1000 of CO_2, existing in
c = air-space,
d = delivery of fresh air required in cubic feet,

then $$\frac{(r_1 - r) \times c}{r} = d;$$

that is, as the admissible limit : excess of existing over admissible ratio :: amount of air-space : amount of fresh air required. Thus, if there be one person in a cubic space of 1000 feet, at the end of one hour the CO_2 exhaled will be ·6 cubic foot = ·6 per 1000: then $\frac{(\cdot 6 - \cdot 2) \times 1000}{\cdot 2} = 2000$ = cubic feet of fresh air required during the first hour.

Again, if there be three muscular adult males, averaging 12 stone in weight, in a space of 2000 cubic feet, and the CO_2 evolved $= 3 \times \cdot 7 = 2\cdot 1$ cubic feet, which in a space of 2000 cubic feet $= \frac{2\cdot 1}{2} = 1\cdot 05$ per $1000 = r_1$;

then $$\frac{(1\cdot 05 - \cdot 2) \times 2000}{\cdot 2} = 8500 \text{ cubic feet}$$

= 2833 cubic feet per head required during the first hour.

After the first hour the size of the cubic space is of little consequence in most cases, the amount of fresh air required from without depending on the amount of CO_2 exhaled. In the example just given 2833 cubic feet per head were required during the first hour; after this, whether the cubic space be 200 feet or 2000 feet, the delivery of fresh air must be $\frac{e}{r} = \frac{\cdot 7}{\cdot 2}$ $= 3{\cdot}5$ thousands $= 3500$ cubic feet every hour.

3. In formula (1) if r_1, the observed ratio of impurity, be substituted for r, from the condition of the air shown thereby may be calculated the amount of fresh air supplied and utilised:

$\frac{e}{r_1} = d =$ amount of fresh air that has been supplied and utilised.

Thus, if the CO_2 due to respiratory impurity be found to be 1·05 per 1000, the CO_2 exhaled being ·7 cubic foot per head,

then $\frac{\cdot 7}{1{\cdot}05} = \cdot\dot{6} = \cdot\dot{6}$ thousands $= 666$ cubic feet per head per hour supplied.

4. To calculate the probable condition of an air-space to which a known quantity of air has been supplied:

$$\frac{e}{d} = r_1.$$

Let $e = \cdot 6, d = 3000$; then $\frac{\cdot 6}{3000} = \cdot 0002$ cubic foot CO_2 per cubic foot of air $= \cdot 2$ per 1000 (or this may be stated as $\frac{\cdot 6}{3} = \cdot 2$).

Again, let $e = \cdot 7$, $d = 1200$; then $\frac{\cdot 7}{1200} = \cdot 00058 = \cdot 58$ per 1000 CO_2.

5. If the figures on page 14 be taken as fairly representing the average weights of adults, male and female, and children, and (in round numbers) the quantities of CO_2 excreted hourly, the amount of fresh air required will be as follows:

Amount of Air required hourly, in cubic feet.

—	In repose	In gentle exertion	In hard work
Adult males . .	3000	4500	9000
Adult females .	2000	3000	6000
Children . .	1500	2250	4500

For muscular adults weighing over 12 stone—as, for instance, navvies—a larger amount would be required, about 3600 cubic feet in repose, with a proportionate increase, under the circumstances of light and hard work.

6. *Amount required for lights.*—For each cubic foot of gas burnt Wolpert has calculated that 1800 cubic feet of air should be supplied, whereby the ratio of CO_2 due to combustion would be kept down to about 1·1 per 1000, and the sulphur dioxide and other combustion-products safely diluted. Each ordinary gas burner would require from 5400 to 9000 cubic feet of air per hour. Oil lamps and candles do not generally require a special supply of air, not because the CO_2 evolved by their combustion is less, for equal illuminating powers, than by that of gas, but because so much more gas is generally burnt, giving more light and heat, and causing much greater deterioration of the air of the room.

HOW MUCH INITIAL CUBIC SPACE OUGHT TO BE PROVIDED FOR EACH INMATE?

The amount of fresh air required per head having been agreed upon, according to the foregoing considerations, the answer to the question of how much cubic space is needed will depend on the ease with which the air in the air-space can be renewed. The larger the room the less frequently need the contained air be displaced by fresh air from outside; the smaller the room the more often must this change take place, and the greater difficulty is experienced in doing this effectually without causing draught. In an air-space containing 1000 cubic feet per head the air needs only to be changed three times in an hour to provide the necessary 3000 cubic feet; but if the space is not more than 500 cubic feet, obviously six changes per hour are required to supply the same quantity of fresh air. With the best mechanical means of ventilation even this can be effected without perceptible draught, as in Pettenkofer's experimental room at Munich, where 2640 cubic feet are drawn hourly by a steam engine through a space of 424 cubic feet. But in temperate climates and under ordinary circumstances three changes per hour are all that can be borne; more frequent change than this produces cold currents of air and draughts. Therefore, for sleeping apartments generally, 1000 cubic feet per head should be allowed; in the case of children and old people so large a space is not necessary—probably 500 to 600 cubic feet would be sufficient. These dimensions are higher than are usually allowed, but, as Dr. Parkes says, 'after all, the question is, not what is likely to be done, but what ought to be done; and it is an encouraging fact that in most things in this world when a right course is recognised it is somehow or other eventually followed.'

AMOUNT OF FRESH AIR AND CUBIC SPACE REQUIRED IN HOSPITALS, SCHOOLS, &c.

Hospitals.—It would naturally be expected that a greater quantity of fresh air would be required to keep the air of a sick-chamber in a good condition than the air of a similar room occupied by the healthy. Dr. de Chaumont's observations point to the conclusion that about one-fourth more fresh air should be supplied, as the smell of organic matter was quite distinct in hospitals when the CO_2 due to respiratory impurity was 0·166 per 1000, as against 0·208 per 1000 in rooms occupied by healthy persons; therefore the hourly supply should be 4000 cubic feet.

The cubic space should be increased in at least the same proportion, viz. from 1000 to 1250 or 1300 feet. The impurities derived from the bodies of the sick ought to be removed as quickly as possible, and being to a large extent particulate, and therefore not removable by diffusion, there is all the greater need for a large dilution with fresh air and exposure to its oxidising and purifying effects; this can only be done efficiently with ample cubic space, as draughts have especially to be avoided in the case of sick-rooms. For purposes of convenience of nursing and attendance a floor-space of 100 or 120 square feet is considered desirable in hospitals; with a height of 12 or 18 feet this would give from 1200 to 1500 cubic feet. These measurements are applicable to ordinary cases of sickness; in certain cases where there are offensive discharges, and in cases of infectious disease, especially typhus fever, and in pyæmia, a much larger amount of fresh air must

be supplied—5000 or 6000 or more cubic feet hourly—indeed, treatment in what is practically the open air often has the best results.

Schools.—The amount of fresh air required for children has been already stated, p. 19; of course this requires modification according to age. The cubic space provided by the London School Board is 130 cubic feet per head, being 10 square feet of floor-space and 13 feet of height. The Education Department of the Privy Council endeavour to secure at least 80 cubic feet and 8 square feet for each unit of average attendance in public elementary schools in England. Carnelley, Haldane, and Anderson found an average of 160 to 170 cubic feet per head in the Board schools of Dundee. In France the allowance is from 120 to 140 cubic feet per head. All these dimensions seem smaller than would theoretically be deemed advisable: with 200 cubic feet per head the air would require changing six times per hour to keep the CO_2 due to respiratory impurity down to 0·25 per 1000 vols.

$$\left(\frac{e}{d} = r_1 : \frac{\cdot 3}{6 \times 200} = \cdot 00025 \ CO_2 \text{ per cubic foot.}\right)$$

The headaches and other symptoms ascribed to over-pressure in Board schools may often really be attributable to the breathing of a foul atmosphere for many hours in succession. In the Dundee schools, however, that were ventilated by mechanical means, the above observers found a fairly good condition to exist, in spite of the small cubic space; the CO_2, however, was high (judged by the standard adopted in this article), averaging ·89 per 1000 vols. above that in the outside air. The standard proposed by Messrs. Carnelley, Haldane, and Anderson for schools is 0·9 vol. CO_2 per 1000 above outside air, 2 vols. of oxygen per 1,000,000, and 20 micro-organisms per litre.

Factories.—The special circumstances resulting from the different kinds of operations carried on in different factories will modify the general rules that have been laid down; in a great many cases special impurities are added to the air, which require removal by special means in order to maintain a wholesome condition of the air-space.

MEASUREMENT OF CUBIC SPACE

The measurement of the amount of cubic air-space in any room or inhabited place may be conveniently carried out as follows:—

1. If the room be square or oblong, with a flat ceiling, the cubic space will be simply the three dimensions of length, breadth, and height multiplied into each other. If the room be circular, or of irregular form, with a curved ceiling or with irregular projections, the rules for the measurement of circles &c. must be used. Irregularly shaped places, if rectilinear, can be divided into triangles and then measured; or, if bounded by curved lines, they can be divided up into segments of circles &c.

2. The room having been measured, all recesses, such as doorways, window-recesses, &c., should be added in.

3. All projections, such as cupboards, solid pieces of furniture, &c., should be deducted.

4. Deduction must be made for the cubic space occupied by the inmates; an average amount of space so occupied by adults is 3 cubic feet; an approximate rule is *weight in stones* ÷ 4 = *cubic feet occupied.*

5. In the case of bedrooms deduction must be made for bedding and bed furniture, which may occupy on an average about 10 cubic feet for each person.

It is more convenient to make the measurements in feet and decimals of a foot than in feet and inches.

Rules for Superficial Measurement.

Area of circle . . $= \pi r^2 = 3{\cdot}1416 \times$ square of radius.

,, $= \frac{C^2}{4\pi} =$ square of circumference $\times {\cdot}0796$.

Circumference of circle $= \pi 2r = 3{\cdot}1416 \times$ diameter.

Diameter of circle . $= \frac{C}{\pi} =$ circumference $\times {\cdot}3183$.

Area of ellipse . . $= \frac{\pi l s}{4} = 3{\cdot}1416 \times \frac{1}{2}$ long diameter $\times \frac{1}{2}$ short diameter.

Area of square . . = square any one of the sides, or, multiply one side into another.

Area of rectangle . . = multiply together two sides perpendicular to each other.

Area of a triangle . = base $\times \frac{1}{2}$ height, or height $\times \frac{1}{2}$ base.

To find area of any rectilineal figure: divide into triangles and take the sum of their areas.

Area of segment of circle $= (\frac{2}{3} \times \text{chord} \times \text{height}) + \frac{\text{cube of height}}{2 \times \text{chord}}$.

Rules for Cubical Measurement.

Cube or *solid rectangle* = length $\times$ breadth $\times$ height.

Solid triangle . . = section area of triangle $\times$ height.

Cylinder . . . = section of area of base $\times$ height.

Cone or *pyramid* . = area of base $\times \frac{1}{3}$ height.

Dome . . . . = area of base $\times \frac{2}{3}$ height.

Sphere . . . $= \frac{4\pi r^2}{3}$ or, diameter cubed $\times {\cdot}5236$.

Nearly every inhabited space can be divided up into figures which can be measured according to the above short rules. For instance, a bell tent is a cone resting on a short cylinder; a hall with a semicircular roof is a half cylinder resting on a rectangle, or if with a segmental roof it must be measured as a solid segment of a circle.

EXAMINATION OF AIR

For hygienic purposes we can obtain much information by considering the subject in the following general order :—

1. By the senses.
2. Chemical examination of the constituents of air.
3. Microscopic examination of the suspended matters in air.
4. A study of the micro-organisms obtained by cultivation from air.

Examination by the Senses

It is now generally admitted that it is the organic matter in air, either suspended or in the form of vapour, that is the impurity we have chiefly to deal with in inhabited air-spaces, and that it is this which gives the peculiar fœtid smell so disagreeable on entering an ill-ventilated air-space. It seems also certain that these organic products are in some way closely connected with the humidity.

Though the nature of this organic matter varies to some extent, but one fact remains clear—we must dilute the air in the air-space with pure air until the amount present, as judged by the sense of smell, does not differ *sensibly* from the external air. Fortunately we have not to depend on this test alone, for observations show that the amount of organic impurity increases *pari passu* with the carbon dioxide evolved by the persons &c. inhabiting the air-space. Dr. de Chaumont, who was the first to formulate a definite rule, adopted as a *standard* the point at which there is no sensible difference between the air of an inhabited space and the external air as determined by the sense of smell. This he reduced to four orders or classes as follows:

1. 'Fresh,' or not differing sensibly from the outer air.
2. 'Rather close,' indicating the point at which organic matter becomes perceptible.
3. 'Close,' indicating the point at which organic matter becomes decidedly disagreeable.
4. 'Very close,' organic matter offensive and oppressive, indicating the point at which the differentiation by the senses is reached.

From the analyses of the different classes and the data these gave the following conditions of ventilation were arrived at:—

1. 'Fresh': Temperature about 63° F. Aqueous vapour shall not exceed 4·7 grains per cubic foot. Carbon dioxide shall not exceed the amount in the outer air by more than 0·2 per 1000 volumes. Ventilation here is good.
2. 'Rather close': Vapour in a cubic foot of air exceeds 4·7 grains. Carbon dioxide in excess over outer air, ratio reaching 0·4 per 1000 volumes. Ventilation here ceases to be good.
3. 'Close': Vapour exceeds 4·7 grains per cubic foot. Carbon dioxide in excess over outer air to the amount of 0·67 per 1000 volumes. Ventilation here begins to be decidedly bad.
4. 'Very close': Vapour reaches 5·1 grains per cubic foot. Carbon dioxide in excess over the amount in the outer air beyond 0·9 per 1000 volumes.

Chemical Analysis

This should include the following points:—

1. The amount of CO_2. This is taken as a measure of all impurities.
2. The amount of oxidisable substances, as judged by the amount of oxygen absorbed from a standard solution of potassium permanganate.
3. The amount of free ammonia.
4. The amount of albuminoid ammonia.
5. The amount of nitrous and nitric acids.
6. The presence of sulphuretted hydrogen or any of its compounds.
7. The presence or absence of ozone.
8. The amount of watery vapour.

1. *Estimation of Carbon Dioxide*

For its determination the following method, introduced by Pettenkofer, is the one usually adopted on account of its simplicity and practical utility. A glass jar or vessel capable of holding about one gallon is taken, and its capacity accurately measured; this is best done by filling the jar with water and measuring the contents by means of a litre or pint measure. Dr. Angus Smith recommends extracting the air from the bottle by a bellows, while Mr. Wynter Blyth would fill the jar by the same means. In the latter method there is always great danger of introducing impurities. Perhaps the best plan is to fill the jar with clean water and empty it in that part of the

air-space it is desired to examine, taking care to allow it to drain well. When this is done 60 c.c. of caustic lime or baryta water are put into the jar and the mouth closed with an india-rubber cap. The vessel is then slightly tilted, first on one side, then on the other, so as to allow the lime or baryta water to run over the sides, and to thus facilitate its exposure to the air.

If lime water is used, the vessel and its contents should be allowed to stand for six or eight hours; but if baryta water has been selected, a much shorter time is sufficient—less than an hour.

The CO_2 is absorbed by the lime or baryta water, and the causticity of these substances is lessened in proportion. The loss of strength of the lime water therefore measures the amount of carbon dioxide present. Freshly prepared lime water is perhaps the most convenient, and the indications given with it are sufficiently accurate for all purposes.

The causticity of the lime water is determined by means of a solution of crystalline oxalic acid, which is made as follows:—

Lime. Oxalic acid.

$$56 : 126 :: 1 : x = 2{\cdot}25.$$

If therefore 2·25 grammes of oxalic acid are dissolved in 1 litre of distilled water, we have

1 c.c. = 2·25 milligrammes of oxalic acid.

1 c.c. neutralises 1 milligramme of CaO, forming oxalate of lime.

Take 30 c.c. of freshly prepared lime water and exactly neutralise with the standard oxalic acid solution. Several 'indicators' may be used for determining the exact point of neutralisation, but good turmeric paper is generally the one most available; a solution of phenol-phthalein gives very exact indications; when the point of neutralisation is reached the pink colour is discharged. The milligrammes of lime in the 30 c.c. are equal to the number of c.c. of the oxalic acid solution used, and this is usually between 30 c.c. and 40 c.c.

After the lime water in the jar has absorbed the CO_2, 30 c.c. of the solution are taken out and tested with the standard oxalic acid solution as before; the difference shows the milligrammes of lime which have united with the CO_2. The milligrammes of lime must be converted into CO_2 by calculation of the proportion between their molecular weights, then the CO_2 converted into cubic centimetres by calculation of the proportion between weight and volume.

In measuring the total capacity of the jar 60 c.c. must be deducted, this being the space occupied by the lime water put in. State the capacity in litres and decimals; divide the c.c. of CO_2 obtained by the corrected capacity of the jar; the result is the c.c. of CO_2 in a litre or per 1000 volumes of air.

Example.—

The first alkalinity of the lime water was for 30 c.c.	39·0
After exposure in the jar	33·0
Difference = milligrammes of lime	6·0
Multiply by factor	·795
	4·770 = total c.c.'s of CO_2 in jar
Capacity of jar	= 4385
Deduct 60 c.c. for space occupied by lime water	60
Net capacity	= 4325 c.c. or 4·325 litres.

Then 4·770 ÷ 4·325 = 1·103 of CO_2 per litre or volumes per 1000.

The factor ·795 is obtained as follows. The milligrammes of CO_2 are obtained by calculating from the ratio of the equivalents of lime and carbon dioxide.

CaO		CO_2		Mgm of CaO		Mgm of CO_2
56	:	44	::	a	:	x;

$$\text{therefore} \quad x = a \times \frac{44}{56}.$$

As 1 c.c. of CO_2 at 32° F. weighs 1·9767 milligramme, the ratio between volume and weight is $\frac{1}{1·9767} = ·506$.

Therefore $x \times ·506 =$ c.c. of CO_2. As 60 c.c. of lime water were put into the jar and only 30 c.c. taken, the result must be multiplied by 2. Therefore we have $\frac{44}{56} \times ·506 \times 2 = ·795$.

Corrections for temperature must be made if this deviates materially from 32° F., this being the temperature at which all gases are measured. If the temperature of the air-space we propose to examine be above this, the air is expanded, and we shall be operating on a smaller quantity by weight than at the standard temperature. If, on the contrary, it is below 32° F., we have a larger quantity of air to deal with, and an addition or subtraction must be made accordingly. This correction may be stated as 1 per cent. for every 5° F. above 32° F.; the factor ·795 is only true for the temperature at 32° F. For each degree of temperature there is an increase or diminution of ·002 in the volume of air, i.e. ·2 per cent. or 2 per 1000; for example, 1 litre of air at 32° F. = 1000 c.c. This will expand at 33° F. to 1002 c.c., and will contract at 31° F. to 998 c.c.; so that if we are working at a higher temperature we are taking up less air by weight in our jar, and if at lower temperatures more air. If, therefore, the temperature is 5° F. above 32° F. *add* 1 per cent., if below *subtract* 1 per cent. from the amount found. For example, if the CO_2 per 1000 volumes = ·6433 at a temperature of 55° F., then $55° - 32° = 23°$ ∴ $23 \times ·2 = 4·6$ per cent. to be added; that is, 100 volumes become 104·6 volumes when raised from 32° F. to 55° F., or 1 volume becomes 1·046.

Then:

$$1 : 1·046 :: ·6433 : x,$$
$$\text{or, } 1·046 \times ·6433 = ·6728 \text{ volume per 1000.}$$

The correction for degrees Centigrade is ·3665 per cent. for each degree.

Correction for pressure is also necessary when the experiment is made much above sea-level, or when the barometer reads below the standard height taken, as $\frac{1}{10}$ inch of pressure causes a difference of ·26 per cent. The standard height of the barometer for which all observations are corrected is taken at 29·92 inches, or 760 mm.; for example, if the experiment is made when the barometer reads 29 inches, then

$$29 : 29·92 :: \text{observed } CO_2 : \text{corrected } CO_2;$$

or if the barometer reads 31 inches,

$$31 : 29·92 :: \text{observed } CO_2 : \text{corrected } CO_2.$$

Although this method for determining the CO_2 in air does not give quite accurate results, it is the most convenient for ordinary use, and sufficiently accurate for all practical purposes.

Dr. Angus Smith has proposed a very simple process for determining approximately the amount of CO_2 in any air-space. It is found that a certain amount of carbon dioxide is required to cause a given volume of lime water to become turbid. Half an ounce of perfectly clear lime water when shaken

with the air contained in a bottle of 20·63 oz. capacity does not become turbid if the air in the bottle contains only 0·3 per 1000 of CO_2, but if 0·4 per 1000 be present a white precipitate is produced. A bottle of 15·16 oz. capacity does not render half an ounce of lime water turbid when the air contains 0·4 per 1000 of CO_2.

Taking this point of 'no precipitation' (temperature of the air at 32° F. and pressure 29·92 inches) with half an ounce of lime water, which should be saturated and clear, as the test point, and varying the bulk of the air shaken with it, Dr. Smith arranged his process which gives results sufficiently close for ordinary purposes. In the following table are given the results of the determinations of the volume of air containing different percentages of carbon dioxide, that half an ounce of lime water containing ·0195 gramme of lime will bear agitation with and give no turbidity. In the table allowance is made for the space occupied by the half-ounce of lime water.

Size of bottle in ounces	Size of bottle in cubic centimetres	Volume of air in cubic centimetres	Carbon dioxide in the air per cent.	Size of bottle in ounces	Size of bottle in cubic centimetres	Volume of air in cubic centimetres	Carbon dioxide in the air per cent.
20·63	584	571	·03	6·00	170	156	·11
15·60	443	428	·04	5·53	157	143	·12
12·58	356	342	·05	5·15	146	132	·13
10·57	299	285	·06	4·82	137	123	·14
9·13	259	245	·07	4·53	128	114	·15
8·05	228	214	·08	3·52	100	86	·20
7·21	204	190	·09	2·92	83	69	·25
6·54	185	171	·10	2·51	71	57	·30

It is necessary that white glass-stoppered bottles should be used, and of the best description. The lime water should be delivered into the bottles as rapidly as possible by means of a glass pipette measuring the exact quantity.

2. *Estimation of Oxidisable Substances in the Air.*

To determine these a definite quantity of air is drawn through a solution of permanganate of potassium of known strength, and the amount of undecomposed permanganate observed by means of the standard solution of oxalic acid, or part of the water through which the air has been drawn may be used for the purposes of examination and the oxidisable matter in it be determined by Tidy's process (see article on WATER ANALYSIS). This latter process includes two determinations: viz. one finding the oxygen absorbed in fifteen minutes and the other the amount taken up in three hours. The experiments are carried on at a temperature of 80° F.

Carnelley and Mackie have proposed a modification of the permanganate process, for which are claimed the advantages of rapidity and simplicity of execution, as well as a higher probability that the organic matter is fully absorbed. The solution used is of the N strength, of which 1 c.c. = ·008 mgr. of oxygen = ·0056 c.c. of oxygen at 0° C. and 760 mm. It is usually kept of $\frac{10}{N}$ strength and diluted as required, about 50 c.c. of dilute sulphuric acid (1 to 6) being added to each litre of the weak solution.

The air is collected in large well-stoppered jars of about 3·5 litres capacity. Before use the jars are drained and the contained air extracted by pumping with a small bellows and allowing the air to be examined to flow in: 50 c.c. of the standard permanganate are next run into the jar, which is then tightly stoppered and well shaken up for at least five minutes; 25 c.c. of the permanganate are afterwards withdrawn by a pipette and placed in a glass

cylinder for comparison. Both are next diluted up to about 150 c.c. with distilled water and allowed to stand for ten minutes, after which the tints in the two cylinders are compared. Standard solution is then run in from a burette until the tints in both cylinders are of the same intensity; usually from $\frac{1}{2}$ to 6 c.c. are required.

The amount of solution added from the burette is a measure of the bleaching effected by the known volume of air in half the permanganate employed. This multiplied by 2 gives the total bleaching.

Example.—25 c.c. of solution from a 3·5 litre jar in which 50 c.c. had been used required 3 c.c. of the permanganate to bring it up to the standard, or the whole 50 c.c. would have required $3 \times 2 = 6$ c.c. This represents the number of c.c. of standard permanganate bleached by $3500 - 50 = 3450$ c.c. of air; consequently $\frac{6}{3{\cdot}45} = 1{\cdot}74$ c.c. is the bleaching effected by 1 litre of air. But 1 c.c. of standard permanganate solution $= {\cdot}0056$ c.c. of oxygen; therefore $1{\cdot}74 \times {\cdot}0056 = {\cdot}0097$ c.c. of oxygen is required to oxidise the organic matter in a litre of air, or 9·7 volumes of oxygen to oxidise the organic matter in 1,000,000 volumes of air.

3. *Examination of the Free and of the Albuminoid Ammonia.*

The estimation of the nitrogenous matter in the air is of importance, as it is mostly derived from the dead and living matter existing in the air, and is useful for comparison with results obtained from pure air. The most convenient plan is to draw the air through a series of wash bottles, each containing 100 c.c. of pure distilled water, by means of an aspirator of known capacity, so that the volume of air passing through may be measured; five bottles are generally used, and these are connected by indiarubber tubing. When a given quantity of air has passed through, the water in the several bottles is mixed together, and the free and albuminoid ammonia determined. The results are calculated in milligrammes per cubic metre.

The object of these processes is to get a measure of the nitrogenous matter present; both give useful information, but they are not always applicable, as it is difficult to complete such an analysis on the spot and the amount of apparatus required renders several consecutive determinations in a series of rooms impossible.

4. *Nitrous and Nitric Acids.*

A part of the water through which the air has filtered may be used for the determination of these acids. To estimate the quantity of nitrous acid present Griess's method may be employed.

For the determination of the nitric acid the aluminium process (Schulze's modified by Wanklyn and Chapman) is perhaps the simplest.

In these processes for the estimation of the organic matter in air the quantity drawn through the water must be accurately measured by a properly arranged aspirator, and the results calculated as milligrammes per cubic metre of air.

The presence or absence of *sulphuretted hydrogen* may be determined qualitatively by means of acetate of lead papers and ammonium sulphide by paper dipped in nitro-prusside of sodium.

Ozone is detected by its action upon potassic iodide. Strips of paper saturated with a solution containing starch and iodide of potassium, dried and exposed to the air for a definite period, are supposed to indicate the amount of ozone present. Ozone causes a blue tint, the depth of which is taken as showing the amount according to a standard scale of tints.

This is not a very reliable test, as nitrous acid and peroxide of hydrogen give the same reaction; light, humidity, and temperature also vary the reaction.

The *hygrometric* condition of the air is ascertained in various ways; by Daniell's hygrometer or Regnault's, which is somewhat similar in principle, or by Dines' hygrometer (see article on METEOROLOGY). In the army the wet and dry bulb thermometers are used, and the relative humidity corresponding to all ordinary readings of the wet and dry bulb thermometers are taken from Glaisher's Tables.

Examination of Micro-organisms in Air.

In addition to the suspended matters found in air, already referred to, micro-organisms are also present. The points of importance to note with regard to them have reference to their number, growth, mode of development, and cultivation in nutrient media. If air is drawn through Hesse's tubes, or if plates covered with sterilised nutrient gelatine are exposed to the air, the aërial organisms are deposited on the surface of the gelatine, and cultivation gives rise to a colony which has a characteristic appearance. From these colonies further cultivations may be made in tubes by inoculation, and the process repeated as long as it may be deemed desirable.

Hesse has shown that when a room is left quiet the micro-organisms settle down and leave the air comparatively free from them. In the case of dwelling-rooms, generally, micro-organisms decrease as cubic space increases. One very important point has been already noticed, the relation of bacteria to moulds in various kinds of air; the purer the air becomes, the more readily, as a general rule, do the bacteria and moulds become equal. The explanation is that the moulds come mostly from the external air. When the air of a room becomes very impure, the bacteria increase, while the moulds remain unaffected.

It was also found that the stirring up of dust altered the ratio. The moulds were little affected while the bacteria increased: the reverse is the case when quiet is established, as the particles to which the bacteria are attached settle more rapidly than the moulds; this is due to the relative lightness of the moulds.

The cultivation of bacteria in solid nutrient gelatine or in agar-agar, after the manner of Koch, is the method generally adopted in air analyses, subject to various modifications. Hesse adopts the following plan. A glass tube of 0·7 metre (28 inches) in length and ·035 metre (nearly $1\frac{1}{2}$ inches) in diameter is carefully sterilised; into this some nutrient gelatine is introduced in a liquefied state and spread out over the whole of the inner surface of the tube by turning it about on its own axis. One end of the tube is closed by an indiarubber cap, with a small glass tube passing through its centre; the other end is furnished with two indiarubber caps, the inner one being perforated; all the portions of the apparatus have been previously sterilised. The liquefied gelatine quickly solidifies and forms a thin layer over the inside of the tube. The apparatus is set working by removing the outer indiarubber cap, and aspirating a known quantity of air through the tube at a slow rate (1 litre in three minutes). The germs present in the air sink down and subsequently develop in the nutrient gelatine.

Dr. Percy Frankland recommends aspirating the air through a small glass tube in which are two plugs of sterilised glass-wool. When the air is aspirated through this tube, the glass-wool retains the germs, and these plugs are afterwards introduced into a flask containing melted nutrient

gelatine and well shaken up. The gelatine solidifies on the sides of the flask, and the colonies can be examined by means of a lens through the glass. Powdered sugar may be used in place of the glass-wool, but this latter mixes so intimately with the gelatine that it is found not to interfere in any way with the growth or perception of the colonies. The gelatine may also be poured on glass plates in the ordinary way, instead of being allowed to solidify within the flask, and if further cultivations are carried on this is by far the most convenient plan.

Dr. Greenleaf Tucker, of Boston, U.S.A., prefers using granulated sugar in a very narrow tube.

Dr. Petri employs calcined sand as a filter in grains of ·25 to ·5 millimetre in size; there are two such filters, each 3 céntimetres in length, kept in position by small wire caps. After the air has been drawn through the sand is poured on to a glass plate, over which liquefied gelatine is then run, and development takes place as in ordinary plate cultivations. It is impossible to say at present which of these methods is the best.

The method of cultivation adopted at Netley is that introduced by R. Koch: this consists of cultivation in solid nutrient gelatine.[1] Glass-wool carefully removed from the tubes by a platinum needle, which has been previously heated to redness, is introduced into a test tube containing liquefied nutrient gelatine. This is then poured into one of Petri's small dishes (which has been sterilised) and in a few minutes becomes solid. The micro-organisms adhering to the glass-wool, if any, being fixed in a solid medium will grow in the places where they have been fixed, and in this way colonies of bacteria are developed, which can be differentiated from one another by various peculiarities of growth.

The enumeration of the colonies that grow on gelatine plates has been carried out by Miquel, by Koch, by isher, and by Percy Frankland, as well as many other observers. The numbers are generally stated as per cubic metre of air, each colony resulting from, and therefore indicating the presence of so many separate forms. It has been shown, however, that the micro-organisms vary enormously in number according to locality, temperature, season of the year, and even time of day. One point that appears to be demonstrated is that the smaller the number of organisms present the purer is the air supply; the numbers diminish rapidly with elevation above the ground level, and after rain.

Dr. A. M. Davies,[2] who has devoted much time to this subject, advocates a systematic description of the naked-eye characters of the different kinds of colonies as being likely to afford valuable indications, and has suggested that they should be described under the following heads. The distinction between Cocci and Bacilli should be noted: then—

A. Those that liquefy gelatine:

Their colour, presence or absence of a deposit and its colour, presence or absence of areola round the liquefied part &c.

B. Those that do not liquefy the gelatine:

I. *Colour.* Generally whitish or yellowish; it may be milky or translucent (colour absent); pale, bright or deep yellow, &c.

II. *Form.* Circular, nearly circular, oval or more or less irregular, branching, &c.

[1] Prepared by extracting half a kilogramme (about 1 lb.) of beef, finely chopped up, with one litre ($1\frac{3}{4}$ pint) of water, with the addition of 10 grammes peptonum siccum, 5 grammes of common salt, and 100 grammes of gelatine, rendered very slightly alkaline with carbonate of sodium, filtered and sterilised by successive boilings. A perfectly clean and transparent medium should result, solid at ordinary temperatures. This is kept in test tubes, about one quarter full, closed with sterilised cotton-wool.

[2] *Army Medical Department Reports*, vol. xxx. p. 348.

III. *Disposition.* The colonies may be raised above the surface of the gelatine, or they may be flat, or excavated in its substance, or cup-shaped.

IV. *Surface.* This may be either moist or dry, shining or dull, or waxy-looking, &c.

V. *Peculiarities.* Such as granular appearance, hard or soft, &c.

If to this be added a description of the character of the growth in different media and on potato, as well as the microscopic examination of the organisms, we have all the information, short of inoculation experiments into living animals, at present at our disposal from which to draw conclusions. It certainly appears advisable to supplement any chemical examination of an air-space by an investigation of the characters of the micro-organisms present, in the hope that as our knowledge increases in this branch of scientific research we may obtain in this direction that information which, in many cases, chemical analysis seems incapable of furnishing.

WARMING AND VENTILATION

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INTRODUCTION

1. The closely related subjects of warming and ventilation may be regarded mainly as special technical departments of the sciences of *heat, hydraulics*, and *pneumatics*. In dealing with problems relating to the warming of buildings we have primarily to consider the production and distribution of heat, and with problems in ventilation we are primarily concerned with the mechanical processes involved in the motion of air. But the continuous production of heat requires, as a rule, a continuous supply of air, which may be used for the purposes of ventilation; in fact, heat is one of the most important agents in ventilation, and the distribution of heat is frequently dependent upon the distribution of heated air or heated water. Moreover, the air which is supplied for ventilation often requires to be warmed. It is not therefore practicable to consider the two subjects separately, but, with the view of arranging the facts with which we have to deal, in some sort of order, we shall first consider some of the most important points in the production and measurement of heat and the effects produced by heat upon the physical properties of air and other bodies, and then call attention to some of the fundamental phenomena observed in the motion of air and other fluids before proceeding to the discussion of actual problems in warming or ventilation, or both combined.

2. *Production and Measurement of Heat.*—Heat for the purposes of warming is mainly due to combustion, which is a name given to the chemical action which occurs when the oxygen of the air combines with such substances as wood, coal, oil, or coal gas. Such substances are known as fuels, of which there are many kinds, solid, liquid, or gaseous. The principal constituents of fuels are the solid element carbon and the gaseous element hydrogen, and the various chemical combinations of those two elements. Under certain conditions the fuel unites with the oxygen of the air, the carbon becoming oxidised to form the heavy gas known as carbonic acid, while the hydrogen also becomes oxidised and forms water; the oxidation is attended with the evolution of a large quantity of heat. Thus every pound of carbon in burning forms 3·7 lbs. of carbonic acid gas and gives out enough heat to raise the temperature of 87 lbs. of water from 62° F. to the boiling point (212° F.), while every pound of hydrogen (190 cu. ft.) produces 9 lbs. of water, and in doing so gives out heat enough to raise 417 lbs. of water through the range of temperature from 62° F. to the boiling point. As carbon and hydrogen form the main constituents of fuel, carbonic acid gas and water are the principal products of combustion, and these must be continually got rid of, and air continually supplied to furnish a continuous supply of oxygen, if the combustion is to be maintained. At the high temperature produced by the combustion, the water is produced as vapour and passes away with the carbonic acid gas; it may be diffused through the air, or part of it may be condensed if the products of combustion be sufficiently cooled before they are allowed to diffuse into the outside air.

There is another method of producing heat artificially which, though not used practically, is of very great scientific importance, and is here referred to

especially on account of its connexion with the converse process, the artificial production of cold, or, to speak more correctly, the artificial abstraction of heat from bodies which are themselves cold in comparison with those surrounding them. The method in question is the production of heat by friction. It is a familiar process which needs no description, but what is important to our subject is that the amount of heat which can be produced by the process is numerically related in a perfectly definite manner to the friction which produces it and the distance through which the rubbing surfaces are made to slide. If we consider a large flat mass lying on a horizontal table, and dragged along the table by a weight hanging from a string passing over a pulley at the end of the table, and if we suppose that the weight required to keep the sliding motion just going is, say, 100 lbs., then, by experiments differing in detail, but not in principle, from the imaginary one here described, it has been shown that for every foot which the 100 lbs. falls a certain quantity of heat is produced by the friction and divided between the table and the mass upon it. The amount of heat so produced does not seem large when compared with the amount of heat produced in combustion; for the numerical experiments show that the 100 lbs. would have to fall through 7·72 feet in order to produce heat enough to raise the temperature of a pound of water one degree Fahrenheit, or through 1158 feet to raise a pound of water from 62° F. to the boiling point; a pound of coal would have to fall under similar circumstances through upwards of 2000 miles to produce the same amount of heat by friction as would be produced by its combustion. The falling weight is said to lose energy in falling, and the heat produced between the table and its moving load is the equivalent and representative of the energy so lost. The energy of bodies may take many forms; that of a raised weight is one form only; an equal amount might have been furnished by stopping a mass moving with a sufficient velocity or by allowing a compressed spring of suitable dimensions to resume its natural shape.

Thus heat must be considered as one of the many forms of energy and may therefore be measured as energy is measured. The most common way of measuring a given amount of energy is to estimate how much 'work' it could do. If, for instance, it could be shown that the energy in question would lift a 10 lb. weight through a vertical height of 50 feet, or, what is precisely equivalent, a 20 lb. weight through a height of 25 feet, the amount of the energy would be 10×50, or 20×25, i.e. 500 foot-pounds. In like manner we may express every quantity of heat as so many foot-pounds. This would be the most scientific way of expressing quantities of heat, but it is for several reasons not practicable to employ the actual conversion of heat into work to furnish a working method of measuring heat. It is a well-known fact that if we were to set about measuring the heat produced by the burning of, say, a pound of coal by finding out what work it could be made to do in lifting weights with any engine or apparatus at our disposal, at least nine-tenths of the heat would escape without recording itself as work, though the total reconversion of the remaining one-tenth into heat could be easily managed. While, therefore, we should not lose sight of the fact that heat and work, or energy, are, in one sense, equivalent terms, and that when work is done by heat a certain definite amount of heat necessarily disappears, and *vice versa*, yet we require some more directly applicable way of measuring heat than by finding its theoretical work-equivalent. The practical method, as hinted in the numerical examples given above, is to find the number of pounds of water that can be raised in temperature from 32° to 33° F. by the amount of heat to be measured. We shall call the amount of heat necessary to raise

one pound of water through that range of temperature the lb. F. unit of heat, or British thermal unit. As the result of many experiments it has been shown that the amount of heat necessary to raise the temperature of 1 lb. of water through any degree of the scale of temperature between 32° F. and 212° F. is, though not strictly, yet for all practical purposes, equal to the lb. F. unit; moreover it is not difficult to secure that all the heat developed, say, by the burning of 1 lb. of coal shall be devoted to raising the temperature of a weighed quantity of water, and hence we may express that heat in lb. F. units by the numerical product of the number of pounds of water heated and the number of Fahrenheit degrees through which its temperature is raised.[1]

By a process similar in general principle to that here indicated, the quantities of heat produced by the combustion of known weights of different fuels have been measured. The quantities produced in the combustion of one pound of the commoner fuels are given in a table on p. 122, and the same table gives an estimate of the amount of heat that can be bought for a penny in each case. The quantity of heat produced by the combustion of a fuel of which the percentage composition is known can in general be approximately calculated from the amounts produced in the burning of the several constituents; as these are mainly carbon and hydrogen, the most important data required for the calculations are that the heat of combustion of one pound of carbon is 13,000 lb. F. units, and that of one pound of hydrogen 62,500 such units.

3. *Latent Heat.*—As a general rule the communication of a quantity of heat to a substance raises its temperature, but sometimes the effect of the transference is to change the state of the substance without altering its temperature. Thus every pound of ice, when it melts, absorbs 143 lb. F. units of heat without any rise of temperature being produced, and the boiling away of a pound of water into steam in the air is only secured by transferring to the water 966 lb. F. units of heat, although the temperature of the steam will be the same as that of the water from which it is produced. The heat is then said to be rendered latent, and the amount of heat rendered 'latent' in the fusion or evaporation of 1 lb. of any substance will be called the latent heat of fusion or evaporation, respectively, of the substance. Water evaporates at all temperatures from surfaces exposed to the air unless the air is already saturated with water vapour: this evaporation takes place at the sacrifice of the latent heat, 966 lb. F. units,[2] for each pound evaporated, which if not drawn from a special supply must be furnished by reducing the temperature of the water itself and the bodies in contact with it. On the other hand, a cold substance in very moist air causes a condensation of the water vapour and liberates the corresponding amount of latent heat.

[1] Other practical units adopted for the measurement of quantities of heat are as follows:—

The 'calorie' is the amount of heat required to raise the temperature of 1 kilogramme of water from 0° C. to 1° C.

The 'therm,' suggested by a committee of the British Association (*B. A. Report* 1888, p. 56), is the amount of heat required to raise the temperature of 1 gramme of water from 0° C. to 1° C.

4200 Joules = 1 calorie = 1000 therms = 3·968 lb. F. units,
772 foot-pounds = 1 lb. F. unit = ·252 calorie = 252 therms.

[2] The latent heat of evaporation of water varies slightly with the temperature. It may be approximately expressed by the relation $L = 1092 - 0{\cdot}7\ (T - 32°) = 966 - 0{\cdot}7\ (T - 212°)$, L being the latent heat and T the temperature Fahrenheit. (Rankine, *Steam Engine*, § 214.)

4. *Specific Heat.*—The amounts of heat which can be stored in equal weights of different substances by raising their temperatures through the same range are very different. The number of lb. F. units of heat required to raise the temperature of 1 lb. of a substance through 1° F. is called its specific heat. We give here a table of the specific heats of some substances by which it will be easy to compare the efficiency of different substances for the storage of heat.

TABLE I.—SPECIFIC HEATS

Substance	Number of lb. F. units required to raise the temperature of 1 lb. through 1° F.
Water	1
Ice	·504
Steam (at constant pressure)	·480
„ (at constant volume)	·370
Copper	·0951
Iron	·114
Brass	·0939
Fire brick, Coal and Coke, Wood	about ·2
Air (when the volume is kept constant)	0·169
„ (allowed to expand freely)	0·238

From this table it appears that, weight for weight, water will absorb much more heat for the same rise of temperature than any of the other substances, and when the latent heat of evaporation is added we find that by carrying 1 lb. of steam at 212° F. into a room, and there cooling it to water at 60°, we should have transferred 1118 lb. F. units of heat, whereas, if 1 lb. of air were similarly dealt with, the heat got out of it would have been a very much smaller amount, namely, 36 lb. F. units. If water at 212° F. had been used, instead of steam at the same or slightly higher temperature, 152 units would have been developed, or about four times as much as for the same *weight* of air. When it is remembered that in carrying heat from place to place by carrying heated bodies, the loss of heat during the carriage is greater the higher the temperature to which the heated bodies are raised (if the exposed surfaces are the same), the comparative economy secured by using water instead of air for the purpose will be sufficiently obvious; and yet more so when we consider that the volume occupied by equal weights of air and water at 212° F. is in the ratio of about 1000 to 1, and the air will therefore expose nearly 100 times as great a surface for the same weight.

5. *Distribution of Heat.*—If a number or 'system' of bodies at different temperatures be left to themselves, the distribution of temperature will gradually become uniform by the passage of heat from the hotter to the colder parts of the system. The process of distribution of the heat in any special case would probably be a very complicated one, but it may be analysed as follows:—

i. *Distribution by Conduction.*—The hot portions will communicate heat to the cooler layers in contact with them, and these in their turn will pass on heat to the still cooler layers adjacent, taking more heat from the hotter. In this way a slope of temperature will be established from the hottest to the coldest portions, and the rate of transmission of the heat will depend on the steepness of this slope of temperature. The process of distribution in this manner is known as conduction of heat. As the temperatures of the different portions become more nearly equal, the slope of temperature becomes less, and the flow of heat consequently slower. With

the same slope of temperature equally thick layers of different substances allow widely different quantities of heat to flow through them in equal times. Good conductors are such as allow a rapid flow of heat through them, and conspicuous amongst all substances in this respect are the metals, particularly copper. Bad conductors, on the other hand, under similar circumstances, allow only a comparatively slow flow of heat through them. A perfect non-conductor would entirely prevent the flow, but no such substance is known to exist. If it were not for its fluid mobility, air would be a very good heat insulator, and air prevented from moving about by some substance such as cotton wool or swan's-down is very efficient for preventing the escape of heat from hot bodies. Wood, glass, and asbestos are also very useful, as are, too, indiarubber, wool, felt, fossil meal (Kieselguhr), slag-wool, glass-wool, paper. The loss of heat from steam boilers is now generally considerably diminished by coating them with a thick layer of some badly conducting composition.

In order to compare the properties of various substances with regard to their power of conducting heat we give here a table of conductivities or conducting powers. The numbers in the second column show the amount of heat in lb. F. units which would pass per hour through an area of one square foot of a layer of the substance one inch thick if the two surfaces of the layer differed in temperature by 1° F. Except for copper and iron the data are very uncertain. On this subject authorities differ very widely. See Everett's 'Units and Physical Constants,' §§ 126–141; and Sir W. Thomson, *art.* 'Heat,' § 75, *Encycl. Brit.* (9th ed.) The amount of heat, H, flowing per hour through an area, A square feet, of a slab l inches thick of a substance whose conducting power is K when the difference of temperature is $t°$ F. may be calculated by the formula $H = K\frac{A\,t}{l}$.

Such a formula may often be usefully employed to calculate the loss of heat through walls or windows with a view to determining the quantity of heat that must be supplied to balance such losses, and so keep up the internal temperature of a building. See Box's Heat, p. 212.

TABLE II.—CONDUCTING POWERS

Substance	Conducting power in lb. F. units. (K)	Substance	Conducting power in lb. F. units. (K)
Copper	3225	Water	5·82
Iron	477·4	Air	·16
Lead	113 ?	Wool	·32
Slate	16 ?	Fossil meal	?
Brick	4·3	Glass	6·6
Firebrick	5·1	Eider-down	·31
Asphalt	3·79	Slag-wool	·314
Oak (across the fibres)	1·70	Asbestos fibre	?

ii. *Distribution by Radiation.*—When a hot and a cold body are separated only by certain substances which may be called transparent for heat, the heat passes directly (in all probability in the form of waves similar to waves of light) from the hot to the cold body, only a very small fraction being spent in heating the intervening medium. The form of energy which the heat assumes on its passage through a medium in this manner is called 'radiation.'

All bodies surrounded by transparent media are always radiating heat which may be absorbed or transmitted or reflected by the bodies upon which it falls, precisely in the same way as light.

Indeed, physically speaking, light is but the name given to a special form

of heat-radiation which the construction of our eyes enables us to see. If it falls upon an opaque body some is reflected, and by that we see the body, but some is absorbed and raises the temperature of the body. Of the energy that comes from a glowing body only a small part is visible, the greater part being only appreciable by its raising the temperature of the body by which it is absorbed. All bodies surrounded by transparent substances radiate heat at all temperatures, the amount of heat radiated per second depending upon the temperature in some way which is not yet fully understood. It depends, however, also on the nature of the body and of its surface. A polished metallic surface radiates very little heat as compared with a dull surface, the amount of radiation from polished metal being about one-fifth of that from lampblack, white lead, or any other dull surface at the same temperature.

The power of a body to absorb radiation is the same as its power of radiating at the same temperature; so if two bodies radiate heat, each to the other, the transfer of heat depends on the difference of the amount radiated by the two, and this will be affected by (*a*) the nature and surface of the radiating body; (*b*) the nature and surface of the absorbing body; (*c*) the difference of temperature between the two. Speaking generally, we may say that good radiators are good absorbers; good reflectors are bad radiators; transparent bodies are bad radiators.

The most familiar and important instance of the transfer of heat by radiation is furnished by the sun, whose rays supply us with heat that has passed, as the motion of extremely minute waves, through the ninety millions of miles of transparent space that separate the sun from the earth, and through the earth's transparent atmosphere, passing on its way through strata of air that must be colder than the coldest mountain-tops. The radiation produces no sense of warmth until it is converted into heat in the bodies upon which the rays fall; and from what has been said above it will be clear that a body in the sun's rays may be quite cool if it be transparent, and if opaque its temperature will rise, least if it have a highly polished surface and most if the surface be dull, particularly so if it be dull black. It is a common enough observation that the temperature of a thermometer which has its bulb coated with lampblack and enclosed in an exhausted glass vessel will rise on exposure to the sun's rays to a point not far short of the boiling point of water.

Of the radiation which falls upon a polished surface nearly all is reflected like light from a mirror: from a polished surface of silver 97 per cent. is so reflected; from a polished steel surface 83 per cent. If the surface is coated with lampblack nearly the whole is absorbed and applied to raising the temperature of the lampblack and the substances in contact with it; but if the surface be dull white a great part is diffusely reflected, that is, the radiation is dispersed in all directions in the transparent medium, as though the white surface were itself rendered very hot by the radiation. In this way even a snow-field by diffuse reflection of the sun's rays may produce the same effect as if the snow itself were at a very high temperature. If the surface upon which the radiation falls is in any degree transparent, the radiation is partly transmitted, partly reflected from the polished transparent surface, partly diffusely reflected and the remainder absorbed.

Different substances exhibit remarkable differences in transparency to radiation. Air if dry is extremely transparent, but, according to Tyndall, the water vapour though invisible causes considerable opacity, so that moist air becomes itself heated when heat is radiated through it. Of other transparent substances, glass is the only one which is of great interest to us, and its properties in regard to radiation are exceptional. A plate with a thickness of ·37 inch absorbs half the energy of radiation which falls upon it, transmitting

the other half; but the half which is absorbed consists almost entirely of energy in an invisible form, or dark heat, as it is called; so that the apparent effect of glass in shutting out *light* is very small indeed; though a thick plate is very effective in screening the *heat* of the sun or fire.

iii. *Distribution by Convection.*—The processes of distribution of heat by conduction and radiation are frequently rendered much more rapid by the motion of the liquids and gases set up by inequalities of temperature. If air is in contact with a hot surface, it becomes itself heated by conduction, and therefore specifically lighter than the surrounding cooler portions; the heated air accordingly rises, being pushed upwards by the sinking of the colder air. A steep slope of temperature may thus be maintained and the flow of heat from the hot body greatly accelerated. This process also takes place when one part of a liquid[1] is warmed; but as any liquid is specifically so much heavier than air the distribution by convection is not so easily observed in liquids as in gases; but it always exists in fluids of both kinds as long as the hotter portion of the fluid is specifically lighter than the cooler portion above it.

The convection currents in any closed space, as, for instance, an ordinary room, are in consequence enormously complicated. At every part of the room where the air is being heated or cooled, no matter how slightly, unless the heating is at the ceiling and the cooling at the floor, convection currents are produced. If there is a fire in the room, some of the heat of the fire passes across the room by radiation in direct lines to the walls, floor, and furniture without directly heating the air to any considerable extent. The surfaces upon which it falls absorb part of the heat, communicate heat to the air by conduction in consequence, and cause upward convection currents; other parts of the heat are reflected either metallically, as by a polished surface, or diffusely, as by a dull white surface, to other parts of the room, and cause upward currents as before. On the other hand, the windows are probably colder than the internal air in contact with them, and downward convection currents are the result. The sun's rays passing through windows and being absorbed by the patch of floor or wall upon which they fall cause upward convection currents. Every person in the room causes convection currents by the heat conducted to the air in contact with his skin or clothes. It is easy to get a wind-vane sufficiently sensitive to show the convection current due to the heat of the hand. The air, therefore, of a room with a fire in it on a cold day is in a most complicated state of turmoil, as an examination of the motes in a sunbeam or the beam of an electric lamp will show. Convection currents produced by fires in shafts and chimneys are the agents depended upon very largely for causing the change of air which constitutes ventilation in mines and elsewhere, and success in ventilation depends mainly upon an accurate knowledge of the convection currents produced by all the sources of heat concerned, whether expressly employed for the purposes of ventilation or not.

The convection currents produced by the human body in an atmosphere colder than itself, while they carry off a good deal of heat, are incidentally of great advantage, as they provide the body with a supply of fresh air. In climates where the temperature of the surrounding air is so nearly that of the body (98° F.) that this natural replacement of air does not take place, an artificial commotion is necessary, and is usually made by means of fans worked by hand.

Illustrations of the great complexity of the convection currents in a room may easily be obtained by observing the rapidity and the uniformity of the distribution of odours arising from liquids with strong smell, or from tobacco

[1] Except water for the range of temperature between 32° F. and 39° F.

smoke. The distribution of the smell is accomplished almost entirely by convection, the direct effect of diffusion being small in the time required for the approximately uniform distribution by convection.

Hardly less important to our subject is the convection of heat in liquids on which the distribution of heat by hot water pipes depends, and the comparative uniformity of distribution of temperature in large masses of water is to be referred mainly to the same cause. The principles of the action of convection in liquids and in gases are quite identical, the differences in detail arising from the relatively greater mass of the liquid. The processes of convection of heat by water may therefore be very profitably used to furnish analogues in ventilation problems.

6. From what has been already said, it will be seen that rapidity or slowness of fall of temperature, or rate of cooling, of a hot body surrounded by cooler ones depends upon a number of conditions which must be regarded in designing heating apparatus for special circumstances. In order that a body may cool as rapidly as possible, its specific heat should be small, it should be a good conductor, and surrounded by cold air with freedom of motion, and its surface should be such as to produce the greatest possible radiation of heat. An iron room, painted dead black, on a cold clear night, would probably offer the most instructive example of rapidity of cooling, and conversely, in the sun's rays it would become most rapidly heated. When we desire to provide for the health and comfort of the inmates of a building, rapid changes of temperature are generally to be avoided, if possible, and a room with thick walls of brick (whose specific heat is high) surrounded by a second wall with an air-space between, and painted white outside, with all windows double glazed, and a thick thatched roof or double roof, would satisfy the conditions required for maintaining an equable temperature, and would form a striking contrast to the case of the iron room previously described. On a small scale, the insulation of heat is carried to very great perfection in a Norwegian cooking stove, which consists of a wooden box cased inside with thick layers of felt and having a close fitted felted lid. The hot meats are kept in tins which fit closely to the felt, so that there is no air circulation. The temperature may be so kept up by the heat insulation that the process of cooking can go on for some considerable time. Thus a can of water at 185° F. placed in a Norwegian stove required twenty-nine hours for its temperature to fall to 104° F., the air outside the box being at 68° F.; whereas the temperature of the same can exposed in a room fell through the same range in seven hours, even though the outside air was slightly warmer. It thus appears that the loss of heat may, to a considerable extent, be prevented by suitable arrangements.

The economy of fuel by the prevention of loss of heat from houses is a department of our subject which has not received sufficient attention from architects and builders, or owners. There are, indeed, some causes of loss of heat which it is not desirable to reduce beyond certain limits. A great part of the heat of an open fire passes up the chimney with the products of combustion, but a considerable part of this is effective in producing the necessary ventilation, and is not, therefore, to be regarded as wasted, and the fireplaces can be so arranged that the waste from this cause is as small as is consistent with the adequate efficiency of the chimney for the purposes of ventilation. On the other hand, the heat lost by conduction through outside walls and window-panes is merely wasted, and has to be made up by an increase in the quantity of fuel consumed, if the rooms are to be kept sufficiently warmed. And, further, permanently damp walls are a continual cause of expense in fuel, for they imply a continual evaporation of water

from their surface, and every pound of water so evaporated from the walls of a room means, with an ordinary grate, the burning of an extra pound of coal. This is also sheer waste of heat, and is now prevented in the better-class houses by interposing an efficient damp-course, which prevents the water passing upward from the ground; but it generally goes on uninterruptedly in smaller houses, although the increase in the initial outlay need not be large, and the economy of fuel is of real importance to the tenants.

The loss by conduction through the walls and windows is not so cheaply remedied. Double outside walls with an air-space between them and double glazed windows would, no doubt, involve greater expense than would be made up for by the economy of fuel that would result from their use, and they are therefore only introduced where an equable temperature is of more importance than economy in building. But more might be done than at present in placing the chimney flues of houses so that more of the heat that passes through their sides would be utilised in warming parts of the house instead of the external air. Wooden shutters closed at night would help to prevent the wasteful loss of heat by conduction through the glass panes. There is, no doubt, a general prejudice against such insulation of heat, as we have been used for so long to rely upon the crevices of the windows for the supply of fresh air for ventilation; and the ventilation is even then so inadequate that we have acquired the habit of ventilating a room when it is not being used in order that the insufficiency of ventilation when in use may not become unendurable, and we are unwilling to interfere with our small air supply. But the loss of heat by conduction in no way helps the ventilation, and might be prevented with a thoroughly good conscience if independent inlets were provided for the purposes of ventilation.

PHYSICAL PROPERTIES OF AIR

7. The object of ventilation may be stated in general terms to be the continuous replacement of the vitiated air in a nearly closed space by 'fresh' air. It is generally considered sufficient to draw the supply of air from any position external to the building to be ventilated. But air is a mixture of gases, and may contain many gaseous compounds as impurity; on the other hand, the mixing of air in open places, even in towns, is so rapid that there is no very great difference in the composition of the air drawn from different localities, unless there is some special local source of contamination that alters the character of the supply; thus a more definite meaning is attributable to the terms 'air' and 'fresh air' than would at first seem likely.

Fresh air we may take to be a mixture of gases containing 20·96 per cent. by volume of oxygen and 79 per cent. of nitrogen, with ·04 per cent. (by volume) of carbonic acid gas, besides a quantity of aqueous vapour which varies in temperate climates between 0·5 grain and 20 grains per cubic foot of air, according to circumstances, small traces of ozone, and gaseous impurities of extremely minute amount. Any specimen of air contains also a very large number of solid particles mechanically suspended, the actual number in a cubic inch varying with the locality and the state of the weather.

8. The weight of a cubic foot of air rendered perfectly dry by artificial means varies with the barometric pressure and with the temperature. When the pressure is equivalent to that of 30 inches of mercury, and the temperature is 32° F., the weight of a cubic foot, or *density*, of dry air is 566·9 grains; enough of such air to fill a room of 1000 cubic feet capacity

would consequently weigh 81 lbs., or nearly two-thirds of a hundredweight, so that the weights to be moved in ventilation are not inconsiderable.

So long as the temperature remains the same the density is proportional to the pressure, so that a fall of the barometer amounting to one inch diminishes the density of the air by about one-thirtieth part. This change of barometric pressure may arise from ordinary meteorological changes or in consequence of the air being raised to a height of 900 feet above the ground level. We may express the law relating to the variation of the density of air with the pressure, considering a specific mass of air, by saying that the volume of the mass of air is inversely proportional to the pressure.

When the pressure is kept constant and the temperature changes, the density likewise changes, but always so that the density is inversely proportional to the number of Fahrenheit degrees in the temperature with 459 added; thus, increasing the temperature from the freezing point (32° F.) to the boiling point (212° F.), while the pressure remains at 30 inches, will change the density from 566·9 grains per cubic foot to Δ, where

$$\Delta = 566{\cdot}9 \times \frac{459 + 32}{459 + 212};$$

and in a similar manner the density of dry air at any other temperature may be calculated. Considering, again, a specific mass of air, the effect of a rise of temperature may be expressed by saying that the volume of the air will be increased by $\frac{1}{491}$th part of the volume at 32° F. for every Fahrenheit degree rise of temperature.

Combining these two effects of pressure and temperature, the density, Δ, of dry air at any temperature, t° F., and any pressure, B inches, is given by the formula

$$\Delta = 566{\cdot}9 \times \frac{B}{30} \times \frac{459 + 32}{459 + t} \text{ grains per cubic foot} \quad . \quad . \quad . \quad (1)$$

9. *Dynamical Cooling of Air.*—One important case of variation of the density and temperature of air under special conditions requires consideration; it may be set forth in the following way. Suppose that a room had been hermetically closed when the barometer was at 30 in., and after it had fallen to 29 in. a window was suddenly opened; the air in the room would immediately expand, part being forced out of the opening. This expansion would be unaccompanied by any supply of heat, and the pushing of the external air aside by the internal air escaping represents the performance of a considerable amount of mechanical work. This work must be derived from some source, and it would, in this case, be obtained by the conversion of some of the heat contained in the expanding air into work, and would, therefore, be necessarily accompanied by a diminution of temperature of the air. The fall of temperature produced in this way is easily observed, and is known as dynamical cooling of the air; it would amount to nearly 5° F. in the instance mentioned. The conversion of heat into work occurs whether the expansion is rapid or slow, but in ordinary slow expansion the communication of heat from surrounding bodies would be rapid enough to prevent the thermometer falling any considerable extent. Compression of air produces a corresponding heating effect. Whenever, therefore, expansion or compression of air takes place suddenly, we cannot calculate the density by the formula (1), because we do not know the change of temperature produced. It may, however, be shown that, under the circumstances defined, the relation between the initial and final pressures, and the initial and final densities, is expressed by the equation

$$\frac{p}{p'} = \left(\frac{\Delta}{\Delta'}\right)^{1{\cdot}405};$$

whereas, if the air had been supplied with heat rapidly enough to compensate for the dynamical cooling, and so keep the temperature constant, the relation would have been

$$\frac{p}{p'} = \frac{\Delta}{\Delta'}.$$

When the sudden change of pressure is given, the change of density can be determined, and by aid of equation (1) the temperature of the suddenly expanded air found. To exhibit more clearly the effect of dynamical cooling the following table has been compiled. It shows the density and temperature of air, of which the pressure has been reduced to 30 in. from the number of inches in the first column without allowing any heat to be communicated to it during the expansion.

TABLE III.—DYNAMICAL COOLING OF AIR BY REDUCTION OF PRESSURE

[Air originally at 60° F. Final pressure 30 inches.]

Initial pressure of the air in inches of mercury.	Density after expansion	Temperature after expansion	Initial pressure of the air in inches of mercury.	Density after expansion	Temperature after expansion
	Grs. per cu. ft.			Grs. per cu. ft.	
30	536·3	60·0	60	654·8	− 33·9
31	541·4	55·1	70	684·5	− 52·4
32	546·3	50·4	80	711·4	− 67·7
33	551·2	45·9	90	735·9	− 80·8
34	556·0	41·6	100	758·6	− 92·1
35	560·6	37·5	200	926·2	−158·5
40	582·6	18·7	300	1040·9	−191·6
50	621·3	−11·0			

Thus it will be seen that if a jet of air at 60° F. were blown into a room by a pressure behind the jet of $6\frac{1}{2}$ inches of mercury above the barometric pressure of 30 inches, so that the pressure of the air of the jet after it had issued into the room was reduced to 30 inches, the temperature of the air would be 32° F. if we neglect the heat developed by the friction of the air at the nozzle. In any actual case a great deal of heat would be developed by the friction; indeed, so great a fraction of the work equivalent to the heat converted would be reconverted into heat by friction at a small nozzle, that the cooling effect might be difficult to observe; but the result of the calculation is sufficient to show that it is quite possible to get a flow of cool air, even in the hottest climates, if the air be expanded by the motion of a piston in a cylinder before it passes into the room.

We have supposed that the air is practically protected from heating during expansion by the rapidity of the change of volume, but it is clear that if the expansion takes place in an enclosure whose sides are very bad conductors of heat, the amount of heat gained by conduction will be comparatively small, even if the expansion be slow. Thus it is possible, by means of suitable arrangements of expansion cylinders, to furnish a supply of air cooled by expansion to a temperature considerably below that of surrounding bodies. If the air be compressed instead of being rarefied, a corresponding rise of temperature is produced. The practical application of this principle of dynamical cooling to the refrigeration of ships and other purposes will be considered in a subsequent section. The theory of it is given in a paper by the late J. P. Joule in the 'Philosophical Magazine,' May 1845, p. 375, 'On Changes of Temperature produced by the Rarefaction and Condensation of Air'; and the suggestion of the method as applicable to practical problems of refrigeration or heating will be found in a paper by Sir W.

Thomson ('Glasgow Philosophical Society Proceedings,' vol. iii. Dec. 1852), or still earlier, though in less practicable form, by Professor Piazzi Smyth ('Report of the British Association,' 1850).

10. *Water Vapour.*—In the description of the effect of changes of physical state upon the density of air no reference has been made to the composition of the air, nor has any such reference been necessary, for the behaviour of all gases and mixtures of gases, in respect of change of physical state, follows the same laws, unless the conditions become such that some of the gas condenses to a liquid, or approaches very nearly to the state verging upon condensation. The only constituent of the atmosphere for which such a state is likely to be reached is the water vapour, and it is on this account that the amount of water vapour in the air is liable to such very wide variation. We shall subsequently consider the evaporation and condensation of water in detail and at present only draw attention to the effect produced upon the density of air by the presence of the water vapour. It is easy to calculate this effect when the pressure of vapour in the air has been measured (see below, § 12). Regarding the weight of the cubic foot of moist air as made up of dry air at the pressure $B - e$, and water vapour at the pressure e, we get for the weight of dry air per cubic foot from formula (1)

$$\frac{B-e}{30} \cdot \frac{491}{459+t} \; 566 \cdot 9 \text{ grains.}$$

The weight of water vapour may be taken to be $\frac{5}{8}$ths the weight of the same volume of dry air at the same temperature and pressure; the moisture in the cubic foot will therefore be $\frac{5}{8} \cdot \frac{e}{B} \cdot \frac{491}{459+t}\; 566 \cdot 9$ grains, and hence the total weight per cubic foot, or the density $\triangle$, is given by the formula

$$\triangle = \frac{B - \frac{3}{8}e}{30} \cdot \frac{491}{459+t} \; 566 \cdot 9 \text{ grains per cubic feet.}$$

Moist air is therefore somewhat lighter than dry air at the same temperature and pressure.

11. *Effect of Impurity.*—The effect of the carbonic acid gas in the air upon the density of the mixture is hardly appreciable. The density of CO_2 is one and a half times that of air (1·529), so that replacing one volume in one thousand of air by carbonic acid gas is equivalent to including in the space matter which will increase the weight by $\frac{1}{2000}$th part. This would have been equally well secured if, instead of changing air for CO_2, the air had been compressed, so as to increase the density by $\frac{1}{2000}$th part, or if the temperature had been allowed to fall sufficiently to produce the same change of density. Thus replacing one volume per thousand of air by carbonic acid gas affects the density in the same way as increasing the pressure by ·015 inch or diminishing the temperature by 0·24° F.

The particles mechanically suspended in the air increase the density by the weight of the particles suspended in a cubic foot: this is a very variable amount; in mines, according to Angus Smith, it may be estimated to reach 3 grains. The attention of scientific men has recently been turned to these dust particles with such interesting and important results that a special chapter will be devoted to its consideration.

Among all the striking properties of the atmosphere which we breathe in the open air, perhaps the most conspicuous is the uniformity of its density, under standard conditions, in all parts of the globe and at all altitudes, arising from the uniformity of its composition, as already alluded to. As all the changes of composition, the production of carbonic acid by animal life and combustion, and the absorption of carbon and elimination of oxygen by

plants, take place at the surface, and in very different amounts in different parts of the globe, the uniformity of composition is very remarkable. The thorough mixing of the gases is due to the process known as diffusion, whereby the particles of each of two gases in contact gradually permeate the space open to both, and in a certain time distribute themselves over the whole space, each as if the other were absent. The process of diffusion is itself a slow one, but it depends on the area of surface of contact of the gases. This surface of contact is immensely extended by the mechanical stirring up of the gases by convection currents, and, as we have already seen, convection currents are practically ubiquitous agents with gases of identical nature throughout; the difference of density of the gases offers another cause of currents, so that the mixing of the gases becomes a very rapid process, and a very short time is sufficient for the uniform diffusion of one gas over a room, unless there is some arrangement which especially favours separation. Escaping coal gas, for instance, can be detected all over a closed room, though if allowed to escape in large quantity its specific lightness often results in the formation of a layer of much stronger gas-mixture at the ceiling.

ON WATER VAPOUR IN THE AIR

12. We have already stated that the amount of moisture contained in a gaseous form in the atmosphere is very variable. The cause of the variation lies in the fact that conditions frequently occur under which the vapour condenses to water, and, on the other hand, in the absence of these conditions, evaporation takes place from every exposed water surface or substance moistened with water. The phenomena of condensation of vapour and evaporation of water are exhibited in nature on a very large scale in the formation of rain, fog, and mist, and in the disappearance of precipitated moisture, respectively. The consideration of these phenomena belongs to meteorology, to which the reader may be referred for a description of instruments for determining the amount of moisture in the air (p. 164). But the conditions of evaporation and condensation are of considerable importance to ventilation and warming, for, in order to ensure comfort to the occupants, the air supplied to a room must not be too dry nor yet too moist.

A given cubic space of air can contain only a certain amount of vapour, dependent upon the temperature of the space and upon no other condition; the presence of air or other gases in the space, though it retards the evaporation of water into it, does not influence the ultimate amount of vapour. The evaporation will go on with extreme rapidity if there is very little air pressure in the space—more slowly if the pressure is considerable—until the pressure of the water vapour itself reaches a certain limiting value called the saturation pressure, which depends upon the temperature. The relation between the saturation pressure and the temperature is most concisely expressed by a curve, the vertical height of a point of which shows the pressure corresponding to the temperature expressed by the horizontal distance from a zero line. Such a curve is shown by the thick line of fig. 1. The pressure is given in hundredths of an inch of mercury and the temperature in Fahrenheit degrees.

Air which contains moisture at its maximum, or saturation pressure, is said to be saturated, and its temperature is said to be at the dew-point. Any fall of temperature or slow diminution of volume determines the deposition of moisture. Most frequently the saturation point is passed in consequence of a gradual fall of temperature, arising from the conduction of

heat away from the air by the solid bodies in contact with it; in that case the condensed moisture is deposited upon the cold surfaces, and the air may not even be saturated far from the cold surface. The condensation of an ounce of water vapour implies that 68 lb. F. units of heat have been withdrawn from it in order to dispose of the latent heat of the vapour, besides the amount necessary to cool the air to the saturation point; so that the deposit of an ounce of water upon a window is direct evidence of the passage of 68 lb. F. units of heat at least through the window glass. This is sufficient to reduce the temperature of 375 cubic feet of air through 10° F. so that the deposit of moisture may be used as a tell-tale for any large abstraction of heat by conduction.

A deposit of moisture is sometimes formed upon a wall which is so much

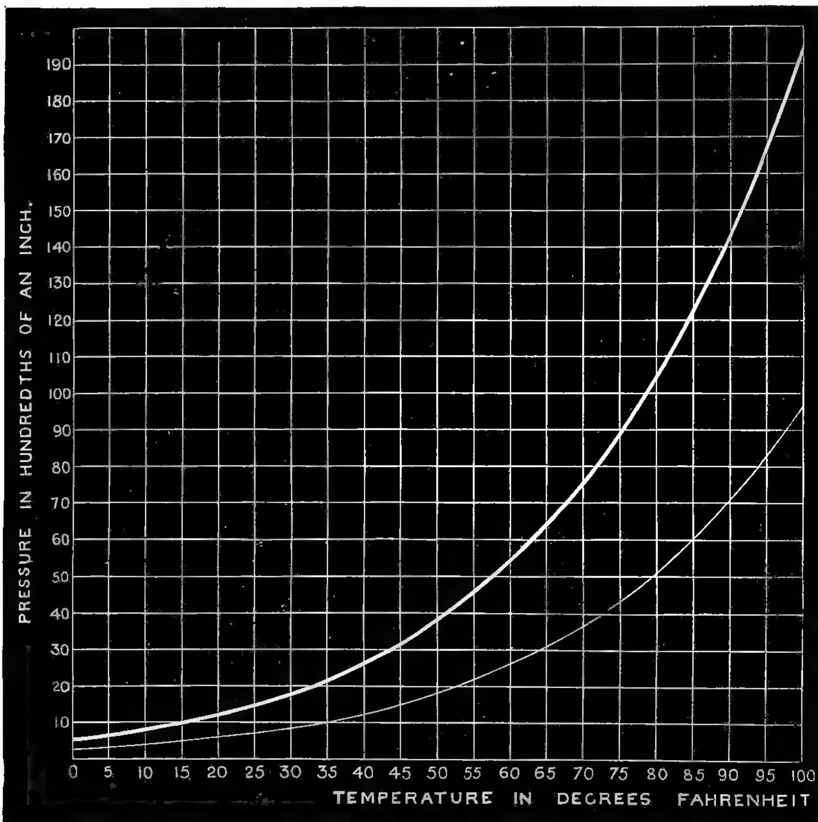


Fig. 1.

cooler than the air in contact with it that the air is reduced in temperature below the dew-point. This phenomenon may arise from two separate causes: first, the replacement of the air by warmer and moister air without any change of temperature occurring in the wall, as when in a sudden change of weather from frost to thaw a warm moist wind replaces the cold air in contact with the outsides of the walls of buildings rendered cold by the previous frost. If the walls are porous the deposit may be absorbed and unperceived. but if they are impervious to moisture, being, for instance, cemented or painted, the beads of damp are very striking, and in this case it is a very common error to suppose that the damp comes out of the walls

instead of being deposited upon them from the air. The second cause referred to operates when the walls of a space are cooled, the internal air remaining unchanged. Instances of this can be tolerably frequently observed in the case of railway carriage windows, which, getting colder at night or on passing through a cold district, show a deposit of moisture on the inside. It is interesting, in many cases, to trace the cause of the deposit of moisture which may be observed, and to decide, for instance, whether the dampness observable on a house-wall is due to a deposit from the inside air, in consequence of the difference of temperature between the wall and the air inside, or to the moisture rising as water from the ground or passing through the wall from some water supply outside the room.

If air is suddenly cooled dynamically, the moisture is not in the first instance deposited upon the solid substances in contact with the air, but on the small solid particles, or dust, floating in the air; these particles loaded with their deposit of moisture form a mist which gradually settles upon the ground as rain, or upon the sides of the vessel if the experiment be made upon a small scale.

Mr. John Aitken has found that solid nuclei furnished by dust in the air are essential to the condensation of vapour in the form of fog, and if no such nuclei be present it is impossible to get the cloud which forms so easily in moist dusty air when suddenly rarefied. Solid surfaces also differ very considerably in their power of causing a deposition of moisture, so that it may be difficult to test very accurately whether air is truly saturated or not. If we regard air as saturated when any very small rarefaction would cause a deposit on the dust nuclei, then certain substances condense the moisture out of air which is not thoroughly saturated. The chemical substances strong sulphuric acid and phosphoric anhydride remove practically every trace of moisture from the air in contact with them; calcium chloride and caustic lime also absorb moisture freely from the air, and may be used to dry it if particularly dry air be required; but these cases must be regarded as instances of chemical actions between the absorbing substances and the moisture. Other substances become damp—possibly on account of fine pores in their surfaces—in air which is not nearly saturated. Wood, whalebone, catgut, are all in their way hygroscopic, and so is hair of any sort when freed from grease. In consequence, a woollen blanket thoroughly dried will condense several pounds of water in its pores in a damp cellar, and a sudden change in the weather from cold to warm will often cause woollen, linen, and cotton materials, especially woollen ones, to become remarkably damp, through the absorption of moisture from moist but not saturated air.

A large quantity of moisture is introduced into the air of rooms by the respiration of human beings and by the burning of gas. Unless the moisture is removed by taking away the heated air, it becomes deposited upon the walls or windows as the room cools down through the night. This leads us to remark upon methods of drying a room, for which it is often supposed to be sufficient to light the gas in it, leaving it shut up. As a matter of fact, but small effect can be produced in this way unless ventilation is provided to carry away the heated air loaded with the moisture, for unless the moisture is actually carried out of the room in some such way, it is simply evaporated by the heat, condensed again upon the windows and walls, and re-evaporated the next day, only to be recondensed in the following night.

Air which is not saturated continually takes up moisture from any surface of water in contact with it, so that a current of dry air passing over a moist surface is a very effective desiccator. The rate at which the evaporation takes place depends upon the amount of moisture already in the air, or

rather upon the ratio of the amount it contains to the amount it would contain if saturated. This ratio is sometimes called the fractional humidity of the air, and is generally estimated by finding the actual pressure of the water vapour in the air and comparing it with the saturation pressure. From the curve of saturation pressure it will be seen that a given fractional humidity will correspond to widely different quantities of moisture in the air according to the temperature. The thin-line curve of fig. 1 (p. 46) is the curve of vapour pressure corresponding to the fractional humidity of the air, ·5; that is, the vertical height of a point on the thin-line curve indicates the pressure of vapour in the air, at the temperature corresponding to the horizontal distance of the point from the zero line, when the air contains half the possible amount of moisture at that temperature. Thus air may be rendered effectively dry without altering the amount of moisture in a cubic foot of it by simply raising its temperature, or it may be rendered effectively damp without adding any water to it by simply cooling it.

Hence arise the differences in the dampness of the same air under various conditions. The external air is sometimes saturated, but it is very seldom in England that the humidity falls below the fractional value ·5. The average humidity in England may be taken at ·75. In inland tropical countries, however, it is frequently much drier than in an insular climate like that of the British Isles.

A wet surface exposed to a current of dry air suffers considerable loss of heat in consequence of the evaporation; thus a body wrapped in wet muslin will have its temperature reduced from 60° F. to 40° F. if it be exposed to a continuous current of air, itself at 60° F., when the fractional humidity of the air is ·24. It follows that damp substances exposed to a ventilation current of very dry air may suffer considerable depression of temperature and cause chills to persons exposed to it. The rapid evaporation, too, from the skin produced by a current of dry air is sometimes injurious, so that ventilation by artificially warmed air is unsatisfactory unless provision is also made for moistening the air to a suitable state of humidity. The humidity should not be less than 60 per cent.

The moistening can only be secured at the expense of the heat necessary to produce the evaporation, and ought to be carried out with due regard for the fact that if the room into which the warmed and moistened air is carried is surrounded by cold walls and windows, the whole arrangement is very similar in principle to a still, and may result in pernicious deposits of water on the walls. This consideration leads us to point out one of the advantages of supplying part, at any rate, of the artificial heat of a room by radiation which primarily warms the walls and tends to keep them hotter than the air, and so prevent any deposit of moisture upon them.

ON DUST AND SMOKE

13. The recent investigations of several scientific men, particularly Mr. John Aitken,[1] F.R.S., and Dr. O. J. Lodge,[2] F.R.S., into the phenomena exhibited by the dust particles carried in the atmosphere, have brought to light and explained some very important facts. As bacterial germs must be included in the category of solid particles conveyed by the air, these recent additions to our knowledge are of great interest to those concerned in securing the purity of the air we breathe.

[1] On the Formation of small clear Spaces in Dusty Air, *Trans. R.S.E.* xxxii. 1884, p. 239. [2] *Nature*, xxxi. 265.

It is unnecessary here to specify exactly the nature of the solid particles that may be found in air. Fragments of all kinds of substances, animal, vegetable, and mineral, may be exhibited. The nature and character of the solid impurities carried by the air will be found fully discussed in the article AIR.

Aitken has recently described a method of actually counting the number of dust particles in a cubic centimetre of air. He first dilutes the dusty air with air altogether free from particles, and when a suitable stage of dilution has been reached he loads the remaining particles, contained in 1 c.c., with condensed water vapour, and thus causes their rapid precipitation upon a measured surface, and then counts the number deposited by means of a magnifying glass. An account of the result of experiments upon a series of different specimens of air is given in a recent volume of *Nature* (xli. p. 394), from which it appears that the number of particles in a cubic inch of 'fresh' air may vary from two thousand in open country to over three millions in cities, and in gas-heated rooms the number may be ten times as great.

The method of determining the number of bacteria in air is dealt with in the article AIR, p. 28.

The suspended dust particles are constantly falling through the air in consequence of the action of gravity, but the rate of fall is very slow, the motion being retarded by the friction they meet with. It is, however, quite appreciable and can be made visible by suitable apparatus and illumination. The dust is maintained in suspension in the air by the currents due to wind or to convection. If the air is still for a long enough period, the dust gradually settles upon all horizontal surfaces, and the air becomes tolerably free from it. A considerable part of the dust of air may indeed be removed by simply allowing the air to flow slowly over a horizontal surface; if the motion is rapid, eddies are produced by the friction of the air against the sides of the channel, and the dust is carried forward and is not allowed to settle. Moreover, if the horizontal surface is wet, the deposit of dust does not take place so freely. The explanation of this phenomenon is probably to be found in the fact that the water is constantly evaporating. The molecules of water are shot out from the surface, and so cause a continuous bombardment of the air next to it; in the process of diffusion the molecules are gradually driven further away from the surface. These molecules are indefinitely smaller than the dust particles, and in the bombardment the dust particles get hammered by the rising water molecules, and are thus driven away from the surface and not allowed to fall. The molecules of the air are themselves in rapid motion, so that the dust particles receive blows from every quarter; but those from the direction of the evaporating water surface predominate, and so the dust is kept at a distance.

In a precisely similar way the dust will be kept off a hot surface exposed to dusty air, which is cooler; only in this case the molecules by which the dust particles are bombarded will all be of the same kind. Those, however, which touch the hot surface rebound with greater velocity than they strike, and so there is a rain of molecules leaving the wall with greater average velocity than that of the molecules of the cooler gas near. Again, the impacts are heavier and the dust is kept off.

Just the reverse effect is produced if the surface is cold and the air warmer; then the predominant effect of the general bombardment drives the particles towards the wall and a deposit of the dust takes place.

When a surface is both moist and warm the repelling action is still more effective, since both causes combine; and to this, as pointed out by Aitken, is probably due our comparative immunity from diseases that might be contracted from the passage of particle-laden air through the bronchial tubes.

The most conspicuous illustration of the phenomena here described is furnished by the deposit of soot in a chimney, the sides of which are cooler than the sooty air passing up the chimney. But on a smaller scale the same phenomenon is exhibited wherever warm dusty air passes over a cooler surface. The subjoined sketch (fig. 2) shows a deposit of soot or dust accumulated on a wall, in eighteen months, over a pair of vertical hot-water pipes which rise from the floor of the room and pass through the wall. It furnishes a very fair measure of the cross-section of the convection current of hot air which is the result of the heating effect of the pipe, and every hot-water pipe near a wall tells a similar tale. A similar deposit can always be observed round the outlet ventilators for warm air, where the dust can often be seen sticking to the edges of the opening like iron filings to a magnet.

If a cold surface be held above the smoky flame of a lamp, a deposit of

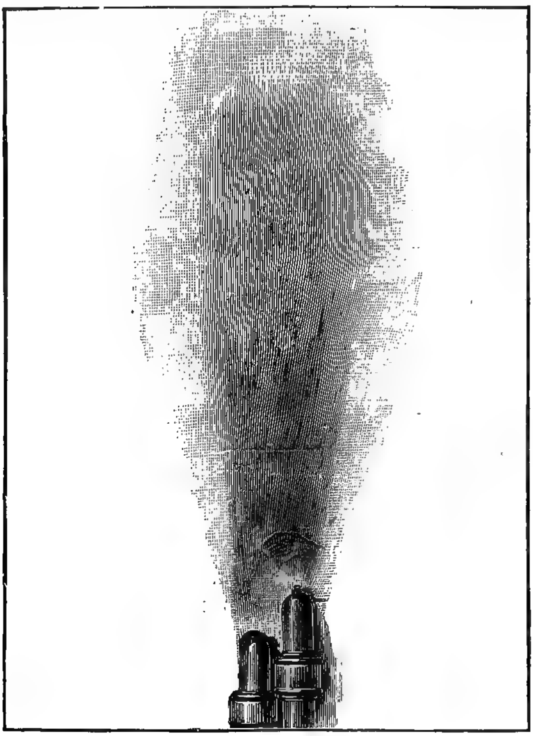


Fig. 2.

soot is at once produced, but if the surface be previously heated no deposit takes place.

The thickness of the dust deposit will depend upon the difference of temperature between the air and the surface, and if there are inequalities in the temperature difference at different parts of the surface the difference in the dust deposit will show it. It is probably on this account that the pattern of the joists above a ceiling is gradually outlined upon the ceiling by a smoke or dust deposit, for those parts of the ceiling which are backed by joists conduct the heat of the room away less rapidly than the intermediate portions.

These dust deposits, which are incidental to water-pipe and hot-air systems of warming, could only be avoided either by securing that the walls are made warmer than the air by means of radiation from open fires or by

introducing the air free from dust. It is not possible to arrange matters so that either plan shall be perfectly feasible, but attention to either or both points may help to reduce the amount of the deposit. The deposits are, however, not without their advantages. Considering the nature of the dust particles, it is sometimes better to have them nailed to the wall than floating about in the air, however unsightly the result may be, for when once fixed to the wall they are not easily dislodged, and they are out of harm's way. Undoubtedly the best way would be not to allow such particles to enter the room with the air supplied for ventilation. A complete air-filter is furnished for small quantities by a plug of cotton-wool moistened with glycerine; but this plan is not applicable where very large quantities of air are required, though large cotton-wool filters are sometimes used. In the mechanical system of ventilation adopted in the chemical laboratory of University College, Dundee,[1] the air is filtered by being passed through jute cloth (light Hessian) stretched on frames 17 feet long by 4 feet wide. In this case the presence of the screen actually increased the delivery of air by nearly ten per cent., probably by preventing eddies. The screens collected $2\frac{1}{2}$ lbs. of dirt in seven weeks. They last about a year, and the cost is about 2*d.* per yard.

A filter of any sort is more effective if it is colder than the air passing through it; so that it would be well to interpose the filter in such a position that the air passes through it after being warmed.

A large chamber into which the warmed air is delivered before being supplied to the rooms would act as a partial filter, from the fact that its walls would be cooler than the air. Indeed, if the air is passed along a narrow annular passage between two coaxal metal tubes, one of which is kept hot and the other cold, the air may be entirely purified from dust;[2] but this plan has only been tested on the scale of laboratory experiment.

In order to take out some of the dust from air introduced by Tobin tubes, a small chamber is sometimes formed at the bottom of the tube, and, the motion of the air in the chamber being comparatively slow, part of the dust falls upon the bottom. A layer of water has been recommended in addition; but this can hardly assist the deposit, for reasons stated above.

It is perhaps hardly necessary to point out that all conduits for air, especially for artificially warmed air, are liable to accumulations of dust, although the air which passes through them may not be drawn from an especially dusty supply. It is well that the dust should be thus deposited in the conduits instead of passing into the rooms; but at the same time it should be remembered that the conduits are liable to become fouled thereby, and to prove a source of serious danger to health unless they are periodically and properly cleaned, and provision should therefore always be made for getting at the conduits for this purpose. Neglect of this precaution sometimes discredits systems for supplying warm air which are otherwise free from objection.

Another method of depositing the dust-particles consists in electrifying them by discharging electricity into the dusty air from a sharp point connected with an electrical machine. The particles then form aggregations and fall. This effect of electrifying dusty air was described by Aitken, but more fully discussed by Lodge. The former has suggested that the effect of thundery weather in turning milk sour, and the like, may be due to the unusual amount of deposit of bacteria in consequence of the electrification; while the latter has discussed the possible application of the method on a large practical scale to the clearing of the atmosphere from fog, dust, or smoke.

[1] Carnelley's *Report on the Heating and Ventilation of Schools*, p. 31.

[2] Aitken, *l.c.*

ON THE MOTION OF AIR. GENERAL THEORY OF VENTILATION

14. The process of continuous ventilation consists in the admission of a quantity of air to a room, or other nearly closed space, through ducts of various forms and sizes, comprised in the general term 'inlet,' and the simultaneous removal of a similar quantity of air by other ducts, which are generally termed 'outlets' or 'exits.' The inlets may be, in any particular case, open doors or windows, special tubes provided for the purpose, or merely the crevices which always exist, as the doors and windows cannot be made to fit perfectly air-tight in their frames. To give a complete account of the motion of the air and its causes is impossible, for it would practically be the solution of a most complicated problem in the motion of gases, as a brief consideration of a simple case will show. Let us take a most elementary system, which may be diagramatically represented, as in fig. 3. The space to be ventilated is represented by the oblong A; it is provided with a single inlet tube, I, and a single outlet, O. The cause of the motion of the air may be as simple as possible, namely, a continuous suction at O, or a blowing in of air at I; and we will suppose that either of these causes corresponds to a difference of pressure, between the external aperture of I and the external aperture of O, which is constantly maintained by some suction or blast apparatus. In consequence of this difference of pressure, air flows along the inlet to A, and an equal quantity flows out of A by the outlet. Now, for a given difference of pressure, say that due to one-tenth of an inch of water, the amount of air which passes through the system depends upon the area of section, the length and shape of the inlet, and the nature of its internal surface, and upon the corresponding properties of the outlet tube; and it is, moreover, affected by any changes of temperature which the air may experience in passing through the system. The effects of these modifying circumstances upon the flow of air, which may be roughly classified as being effects of friction and of temperature, are at best only very inaccurately known, so that the calculation of the amount of flow for any special case is only an approximation; and this is only part of the problem. A complete knowledge of the ventilation of a room refers not only to the amount of air supplied and simultaneously withdrawn, but also to the path which the incoming air takes when it enters the room. It is a matter of the greatest consequence whether the fresh air supplied proceeds directly to the outlet or takes a more devious course. We ought, therefore, to be able in some way to specify the path which the air takes after it enters the room until it is finally disposed of by passing out at the exit; or we might aim at stating the direction in which the air is moving at any point of the room. But the air of any inhabited room is generally, from causes previously mentioned, in a state of absolutely indescribable turmoil, and the precise motion defies calculation. Even if we could perform the necessary calculation under perfectly permanent conditions, we should have solved an ideal problem and not a real one; for the conditions may be said to be practically never permanent. All this refers to the simple system we have imagined, and every actual system is more or less complicated by the multiplicity of inlets

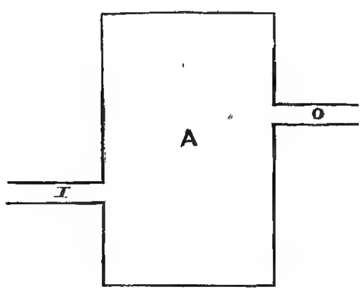


FIG. 3.

and exits, and causes of flow. We cannot, therefore, undertake the complete numerical solution of the general problems of ventilation; but we shall be able to show that certain of the phenomena—for instance, the motion of air through tubes and apertures—do lend themselves to numerical calculation, and the general character of others of them, as the distribution of air-currents in a room, can be inferred from observation of special cases; so that really useful information may be obtained from a consideration of the effects which are likely to be produced under given conditions.

We shall first suppose our questions limited to cases of what is termed 'steady' motion, which may be explained as follows: If we commence drawing air out of a room by suction at one end of the ventilation system, successive portions of the air are set in motion—some of the air of the room is drawn out, the pressure in the room is reduced, and air begins to be drawn in through the inlet. If the suction is maintained perfectly constant for some time, a continuous steady flow is established; that is, as much air comes in through the inlet as is drawn through the outlet; the pressure in the interior is kept diminished, but always by the same amount; and the amount of air in the room does not alter any further; and the same is true of any portion of the space in the inlet or outlet tubes—it always contains the same amount of air, neither more nor less. An observer, if he could see the motion of the air across a transverse section of one of the tubes, would see it constantly flowing at the same rate; in other words, the velocity of the motion of a portion of the air depends upon its position only, and does not vary from time to time. Since the quantity of air in the space which is contained between any two parallel sections of the system is thus invariable, it follows that the amount which crosses the one section to enter the space is the same as the amount which crosses the other section leaving the space. We shall refer to this statement as the Law of Continuity of Flow. It must be remembered that it is the *quantity* of air which flows equally across every transverse section when the motion is steady, and that the quantity flowing is measured by the *weight* of air which passes the section per second or per minute, as the case may be. The *volume* which is occupied by a quantity of air when it leaves the outlet of the system may be very materially different from the volume which an equal quantity actually occupies before entering the inlet, because it may be at a different pressure and different temperature. So that, strictly speaking, the volume of air which crosses any section of a ventilation system is not, by the law of continuity of flow, equal to the volume which crosses any other parallel section, in consequence of the compressibility and expansibility of the air. If we were dealing with a liquid instead of a gas, the changes of volume which can be produced by changes of pressure and temperature within the range of ordinary observation in a mass of liquid like water are so extremely slight, that there would be no practical error in regarding the *volume* of the liquid which crosses any section as being the same throughout the system; and, indeed, even when we are dealing with air, there are many cases in which the variations of volume which take place are comparatively slight, for the differences of pressure and temperature which produce them are not large; so that if we altogether disregard the alteration of volume, and consider the *volume* of air which traverses successive sections to be equal, instead of the weight of air, we shall probably be within the limit of error which is imposed by inaccuracies of measurement. As the quantity of air which crosses any section of a steady ventilation-system is always the same at every part of the system, it is a most important element in the specification of the action of the system; we shall frequently refer to it as the 'flow.' Strictly speaking, it ought to be

measured by the weight passing any section; but as the variations in density of the air along the circulation are slight, we shall generally suppose the flow measured by the volume which passes any section.

To take a specific example. Suppose that we have a room provided with a chimney and a fireplace in which is a gas-jet instead of a fire; and suppose the opening of the fireplace closed by a well-fitting screen with a single circular opening in it; and suppose, further, that we measure, by means of an apparatus to be described later (p. 105), the volume of air which flows through this opening to be 24 cubic feet per minute, the temperature being 62° F., the barometric pressure being at the same time 30 inches: then, referring to equation 1, p. 42, we find that the *weight* of air which passes per minute through this aperture, i.e. the weight of 24 cubic feet at 62° F. and 30 inches, is 12,840 grains; and by the principle of continuity of flow, provided the motion be steady, the same weight of air passes out of the top of the chimney and the same weight enters the room by the chinks in the windows and door. But the volume is not the same, for the entering air will have the temperature of the outside—42° F., suppose; so that the volume of outside air which enters will be diminished to $\frac{459 + 42}{459 + 62} \times 24$, i.e. about 23 cubic feet; and if we suppose the temperature of the air issuing from the chimney to be 150° F., the 12,840 grains when they pass out of the chimney will occupy a volume $\frac{459 + 150}{459 + 62} \times 24$ cubic feet, i.e. about 28 cubic feet. We have left pressure differences out of account, though there is a difference of pressure on the whole of about $\frac{1}{10}$th of an inch in the case mentioned. As this is less than $\frac{1}{3600}$th part of the whole pressure of the atmosphere, the variations on this account of the volume of the air delivered at different parts of its route are so small that they may safely be disregarded.

We have laid down the condition that the motion is steady; if experiment were made upon the actual instance given above, it would in all probability be found that the wind blowing across the top of the chimney, or directly upon the windows, seriously interfered with the steadiness of the motion. In fact, in some actual measurements, the flow through the same aperture in four successive minutes was 24·5, 24·1, 22·9, 25·1 cubic feet respectively. In such a case we have to infer what the flow would be under steady conditions, by taking the mean of a number of consecutive observations, or prolonging one observation over a long period. The effect of unsteadiness due to the wind is less, the greater the flow produced by permanent artificial causes; or, in other words, the observations of artificially maintained ventilation currents are more definite and trustworthy the greater the velocity. This should be borne in mind in considering observations of the flow in ventilation channels. When the artificial current is weak and the wind at all strong or gusty, no observations of any value can be obtained.

The law of continuity of flow may be regarded as the first fundamental principle in the theory of ventilation, and needs only to be stated for its importance to be allowed. It accounts for many of the most easily observed phenomena of ventilation; the disagreeable draught which a fire produces in a room is one of the most familiar instances of its application. At the same time it is one of the principles most frequently disregarded, for, of the number of houses built, only a very small fraction exhibit any evidence of provision for air to enter in a satisfactory manner to replace that which must necessarily be removed by the chimneys and other outlets.

For the purpose of numerical calculation the law of continuity can only be applied to those sections of a system where the motion is steady. The

steady state is generally well established in the ducts by which the air enters or leaves the ventilated space ; but in the space itself local causes interfere with the steadiness of the motion of the air, and may cause the velocity of flow at any point to change from time to time in a manner which cannot be accurately calculated numerically. We must therefore analyse the general problem into two parts and treat them separately. The first part deals with the steady flow through the ducts, and this we will denominate the 'general circulation' in the system ; the laws which regulate it will be stated and exemplified. The second part deals, on the other hand, with the motion of the air in the ventilated space, which is generally irregular ; about this part we can only give the results of observations upon special examples, which will, however, enable us to form a rough estimate of the approximate distribution of flow in a room under specified conditions, and from which some principles of general application can be derived. The irregularity of the motion of the air in the room does not, however, interfere with the general application of the law of continuity, which enables us to say that the total quantity of air entering by the inlets is equal to that which passes in the same time through the outlets.

General Circulation

15. In order to form a definite conception of the laws which govern the flow of air through ducts, we shall first consider their application to a very simple case, and then show how the theory may be extended to more complicated cases. This method of treatment has been suggested by a very instructive work by M. Murgue on 'The Theories and Practice of Centrifugal Ventilating Machines,' translated by A. L. Steavenson. The simple but most typical case of flow of air, which forms the starting-point of the theory, is that in which air is driven through an aperture in a thin plate, when a steady difference of pressure is maintained between the two sides of the plate. We shall not now stop to consider the way in which the pressure-difference can be maintained ; to that part of the subject we shall devote a special section subsequently. We may picture to ourselves two very large spaces—two rooms, for example, A and B, fig. 4.—with a small aperture a in a thin sheet of metal separating them. The pressure in A is to be maintained at the steady value, say P lbs. per square foot, and the pressure in B at p lbs. per square foot. We must, however, make clear what is here meant by the pressure of the air. The motion of air through the orifice will affect the pressure of the air in its neighbourhood ; if we carry an instrument for measuring pressure (for instance, an aneroid barometer made sufficiently delicate to indicate the very minute changes of pressure that occur in such cases) from any remote corner of A towards the orifice, the pressure will remain, practically speaking, constant, until a position quite near to the orifice is reached ; then the pressure will show signs of diminution, and it will continue to diminish until the orifice is passed, and even after that for a very short distance, until we arrive at the position of most rapid motion ; after that the pressure will gradually increase to a uniform value in the space B at any considerable distance from the orifice. We may call those parts where the air has any considerable motion the 'rapids' ; and when we speak of the pressure of the air in the space A or B, it must be understood that the measure is not taken within the rapids. Some idea of the extent of the rapids may be obtained

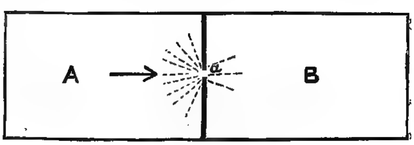


Fig. 4.

from a consideration of the special cases of the flow of air in the neighbourhood of inlets and outlets which will be described hereafter (§ 30).

In consequence of the steady difference of pressure, equivalent to $(P-p)$ lbs. per square foot, a steady motion is maintained through the orifice. At the orifice itself, the air is converging from all directions, so that the 'vein' of flowing air contracts after passing the orifice until the position of maximum velocity is reached. The vein afterwards spreads out again as the velocity diminishes, and has therefore a section of minimum area at the part at which its velocity is greatest; and there, moreover, the direction of the motion of each portion of the air, as it passes, is perpendicular to the plane of the orifice. The general character of the vein of air may be to a certain extent inferred from the analogous case of the motion of water through an opening in a plane plate, or from the flow of a river through the arch of a bridge; the eddies that are formed in the debatable region between flowing stream and dead water have their counterpart in the eddies which are set up in the air beyond the orifice.

There are also other phenomena which the motion of the air exhibits. When air expands on change of pressure the temperature is reduced, so the air in the rapids will be cooled. The differences of pressure which occur in ordinary cases of ventilation are, however, extremely small, and some of the heat is returned to the air by the friction at the orifice and in the space B. In those cases in which a greater difference of pressure is required, as in mines, the flow takes place, not through an orifice in a thin plate, but through long shafts, and the temperature is really determined by the shaft in which it flows; hence we may disregard the changes of temperature that occur in consequence of the expansion.

16. Let us now consider more closely, but still in quite general terms, the conditions that are necessary in order to maintain the steady flow through the orifice. The air will not go through it of its own accord; it requires some agent to drive it—to maintain, in fact, the difference of pressure. There are several practical ways of doing it: blowing with suitably arranged bellows into the space A would be one way; using an engine to drive a fan blast another; maintaining a fire to heat air in a chimney in communication with B, a third; but all these involve the use of working agents—the worker of the bellows, the engine, or the fire as the case may be. To drive a pound of air through the orifice every second requires the expenditure during each second of a certain amount of work, which may be measured in foot-pounds, or the number of pounds weight which the same amount of work would lift through a foot. We shall give a special name to the amount of work, measured in foot-pounds, which must be spent in driving one pound of air through the orifice: it will be called the *Head*, corresponding to the flow. We shall subsequently calculate the head for a number of special cases of circulation, but for the present we shall content ourselves with specifying that when we say that the head for a flow through an orifice is one-tenth of a foot-pound per pound, we mean simply that every pound of air which passes through the orifice uses up in doing so one-tenth of a foot-pound of work. We shall generally denote the head in foot-pounds by the symbol $\mathfrak{H}$.[1]

[1] In order to give a more definite idea of the meaning of the term 'head,' we may refer to the analogous case of the flow of water through an orifice when the water is at different levels on the two sides. In that case the 'head' (or work done in foot-pounds per pound of water flowing through) is equal to the difference of level, h, of the water on the two sides of the orifice. Similarly, in the case of air the head represents the height to which air would have to be piled on the one side of the orifice in order that the difference of weight of the columns on the two sides might produce the same result as the head,

We can consider how the work is spent as the air passes through the orifice, including in the time of the passage of a portion of air the whole time from the instant at which the portion becomes involved in the rapids to the instant when it reaches the most contracted part of the vein. Its velocity becomes gradually accelerated from its initial value, which is practically zero, to the maximum value, which we may take to be v. It is a well-known dynamical principle that to generate a velocity of v-feet per second in a mass of 1 lb. requires $\frac{v^2}{2g}$ or $\frac{v^2}{2 \times 32 \cdot 2}$ foot-pounds of work; hence each pound of air requires for the production of the velocity $\frac{v^2}{2 \times 32 \cdot 2}$ foot-pounds of work, which is subsequently frittered away to heat by the friction in the second space B and lost for all practical purposes. If this were the only way of spending the work, we should have the simple relation between the head $\mathfrak{h}$, and the maximum velocity v.

$$\mathfrak{h} = \frac{v^2}{2 \times 32 \cdot 2} \text{ foot-pounds per lb.}$$

But the calculation, of which the equation just written expresses the result, proceeded on the assumption that the head was devoted entirely to the increase of velocity of the air. This would leave out of account the work which is lost in friction at the orifice; so that the equation as it stands is not directly applicable.

It is fortunately unnecessary for us to attempt to correct it by estimating separately the effect upon the flow which is produced by the convergence of the vein, the friction and the eddies which it causes, and the other phenomena which occur in the rapids. Experiments have shown that the resultant effect can be represented with sufficient accuracy for practical purposes by supposing them to produce a constriction of the area, over which the maximum velocity v may be supposed to be uniform. Thus, what really takes place when a difference of pressure is maintained on the two sides of an orifice is, that air flows through the orifice a in convergent directions and meets with frictional resistance; the flow in the general circulation can, however, be calculated on the supposition that it is equivalent to a flow which passes perpendicularly through a narrower orifice over which the velocity is uniform, and equal to the maximum velocity which the head would produce if there were no friction. The velocity can thus be calculated by the formula given above. The experiments further show that the area of the contracted orifice always bears the same ratio to the actual orifice for different heads, so that the contracted orifice can always be calculated from the actual area, a, of the given orifice by multiplying by a fraction, k, which is called the coefficient of contraction. Thus the area of the contracted orifice is ka. We may now state the resultant effect of the action of a head, $\mathfrak{h}$; it produces a flow which is represented by a uniform velocity, v, of the air perpendicularly across an area ka, where a is the area of the orifice, and k the coefficient of contraction, the velocity at the contracted area being related to the head $\mathfrak{h}$, by the equation $\mathfrak{h} = \frac{v^2}{2 \times 32 \cdot 2}$.

supposing that the air did not vary in density and could have a free surface like water. It follows from this that the difference of pressure on the two sides is that due to a column of air of uniform density whose height is numerically equal to the head, or is equal to that of a column of water whose height is h feet, where $h = \frac{\mathfrak{h}\Delta}{\Delta'}$, Δ being the density of the air near the orifice, and Δ' the density of water. The ratio $\frac{\Delta}{\Delta'}$ is the specific gravity of air referred to water, and may be taken as being approximately equal to 1/800.

We can further calculate what volume of air passes, for it is equivalent to the volume delivered at velocity v through the contracted area ka. If areas are measured in square feet, and velocities in feet per second, the flow will evidently be kav cubic feet per second. Let us call the volume delivered in cubic feet per second V; then

$$V = kav$$

and we get for the relation between the volume V delivered at the contracted area and the head $\mathfrak{h}$ which causes the flow,

$$\mathfrak{h} = \frac{V^2}{k^2a^2 \times 2 \times 32{\cdot}2}.$$

The volume delivered across any other section may be calculated in accordance with the law of continuity of flow; but if we neglect the differences of density of the air at different sections, as we generally may do without appreciable error, we may assume that the *volume* delivered is the same across any section; though, as already pointed out, it is really the weight of air which passes any section which is the same throughout.

The flow through the orifice may as a rule be easily found experimentally by means of an air-meter (see p. 105), which when properly used gives the mean velocity perpendicular to the area. The corrected reading of this instrument gives the value V/a for any opening through which the air flows, and, a being measurable, the value of V becomes a quantity which is capable of fairly accurate experimental determination. It is, in fact, the measurement in relation to ventilation which is most easily carried out in practice, and hence the equation connecting $\mathfrak{h}$ and V is of very great importance. We may regard it as the statement of the *second fundamental principle of ventilation*, the law of relation between head and flow for an orifice in a thin plate.

The constant k is not very accurately known, but it does not differ much from ·65, whatever be the shape of the orifice.[1] In what follows, except where otherwise specified, we shall take its value at ·65, and the law of relation between head and flow through an orifice in a thin plate becomes—

$$\mathfrak{h} = \frac{V^2}{2 \times 32{\cdot}2 \times ({\cdot}65)^2a^2} = \frac{V^2}{27a^2}.$$

We may transpose the equation to the following:

$$\frac{\mathfrak{h}}{V^2} = \frac{1}{27a^2}$$

and we notice that the right-hand side of the equation is a numerical constant for an orifice of given area; so that we may enunciate the second fundamental law as follows:—The ratio of the head to the square of the flow is a constant which is inversely proportional to the square of the area of the orifice; this constant we may if we please call the resistance of the orifice, and express the statement thus:—The head is equal to the product of the resistance of the orifice and the square of the flow, or the flow is equal to the square root of the head divided by the resistance of the orifice, and we may write the equation finally:

$$\mathfrak{h} = R \,.\, V^2,$$

when R is the resistance and V the flow. If the head is expressed in foot-pounds per pound of air and the flow in cubic feet per second, R will be equal to $\frac{1}{27a^2}$ when a is the area of the orifice in square feet. Those who are familiar with ordinary dynamics may prefer the resistance of the orifice expressed in more general terms, so that the condition of referring the head

[1] See Peclet, *Traité de la Chaleur*, i. 154.

and flow to particular units need not be imposed. We therefore write for R its equivalent value, $1/(2gk^2a^2)$, where g is the gravitational acceleration of any falling body, a the area of the orifice, and k the coefficient of contraction.

In concluding this section we may give a definition of the resistance of an orifice in the technical sense in which we shall use the term. It is the factor by which the square of the numerical value of the flow through the orifice must be multiplied in order to give the value of the head which produces the flow.

One of the direct results which follow from this equation is, that we are enabled to calculate the head between the two sides of a thin plate by observing the flow through a measured orifice. For instance, in some observations upon the draught of air the average velocity of the air passing through a circular opening three inches in diameter in a sheet of millboard was found by means of an air-meter to be 8 feet per second. The area of the orifice was ·049 square foot, and the flow consequently ·392 cubic foot per second. The resistance of the orifice may be calculated out to be 15·6; whence it follows that the head required to maintain the flow through the orifice is $15{\cdot}6 \times (\cdot 392)^2$, i.e. 2·4 foot-pounds per pound of air traversing the orifice. From the considerations given in the footnote on p. 54 we see that this head would imply a difference of pressure on the two sides of the orifice which corresponds to a difference of level of ·036 of an inch of water.

Extension of the theory to ducts of any length and form

17. We have hitherto only considered the motion of air through an aperture in a thin plate; but the theory may be very easily extended to any duct whatever. For if we consider the flow of air along a duct, we have losses of head due to friction against the sides of the channel, to sudden bends, or to changes of diameter, besides the loss due to friction on entering the duct, and possibly to the contraction of the vein where the air emerges. All these account for, or use up, part of the head, and the remainder alone is available for producing the velocity which constitutes the flow. But, as will be seen shortly, every one of these items of expenditure of head is proportional to the square of the flow, so that instead of equating the head to a single term $\frac{1}{27a^2}V^2$, we must equate it to the sum of a number of terms representing severally the expenditure of head on friction, bends, changes of diameter, and finally velocity of emergence. Each one of the terms will, however, contain V^2 as a factor; so that the equation takes the form—

$$\mathfrak{H} = (a+b+c+d+ \;\ldots\ldots)V^2, \qquad \ldots \quad (2)$$

where the factors $a, b, c, \ldots$ refer to the losses of head due to the several causes specified. The separate terms may be calculated separately if we have complete information as to the shape, size, and nature of the surface of the duct; but even if we cannot calculate them, we can see that the factors $a, b, c, \ldots$ might at any rate all be added together and the sum of them called R, and we get the equation in the form

$$\mathfrak{H} = R\,V^2 \qquad \ldots\ldots \quad (2^*)$$

which is identical in form with that for the motion through the aperture in a thin plate; only in this case we cannot calculate the value of R, or at least not so easily as for the use of a thin plate aperture. But we can still speak of R as the resistance of the duct, and, as in the case of a thin plate aperture, it is independent of the flow; and, moreover, we can see that different ducts may have the same resistance, and may therefore be regarded as equivalent.

Of two equivalent ducts, one may be an orifice in a thin plate the area of which can be calculated, as we have seen, from the resistance. Hence we may represent the resistance of a duct as the resistance of the orifice in a thin plate to which it is equivalent, and if we can measure the resistance of a duct we can calculate the area of the 'equivalent orifice' in a thin plate, and in this way specify the properties of the duct in regard to the transmission of air. If, for instance, from any cause the resistance of a duct be increased, as by increasing its length, or by a deposit of soot on its surface, we may at once represent the increase by a corresponding diminution in the area of its equivalent orifice.

The definition of the resistance of a duct is identical with that for a simple aperture, namely, the ratio of the head to the square of the flow. If these two quantities can be measured, the resistance can be at once calculated and the area of the equivalent orifice determined. We shall shortly describe methods of measuring the resistance without directly determining the head, and shall thus be enabled to find from such measurements the orifice to which, say, a chimney is equivalent, and to compare different chimneys in respect of their resistance or equivalent orifices, and this without even so much as knowing what the area, shape, or state of the chimney may be.

The idea of expressing the 'conducting power,' if we may so term it, of a duct by means of the equivalent area in a thin plate is, so far as we know, due to M. Murgue. It evidently enables us to render remarkably precise a large mass of information that was before hazy and vague. We may sum up by restating our *second general law of ventilation* in terms applicable to any duct whatever, as follows. The ratio of the head to the square of the flow is a constant called the resistance of the duct, which depends on the size, shape, and surface of the duct, but is independent of the flow, and for the purposes of transmission of air the duct is equivalent to the orifice in a thin plate which has the same resistance as the duct, the area of the equivalent orifice a being connected with the resistance R by the relation $R = \frac{1}{27a^2}$.

Third and Fourth Laws of Ventilation. Application of the first two Fundamental Laws of Ventilation to the Indirect Determination of the Resistance of a Duct and of the Head producing the Flow in a given Duct.

18. We have already seen that one of the characteristic properties of a duct of any shape and length is its resistance to the flow of air through it. It is of great importance to the accurate study of any actual system of ventilation that the resistances or equivalent orifices of its air-ducts should be known. The resistance of any duct may be calculated approximately, in a manner that will subsequently be described, from the measured dimensions of the duct and from its shape, assuming certain experimental results as to the coefficient of air-friction, and the effect of bends and other singularities upon the flow of air. The calculation is, however, elaborate and tedious, and in the end not very satisfactory, except, as already indicated, for the case of an aperture in a thin plate, when the calculation is sufficiently simple and accurate, the resistance of a thin plate aperture of area, a, being, as already explained, $\frac{1}{27a^2}$.

Now it is possible when a flow of air passes through a combination of ducts to infer, from observations of the flow merely, the relations between the resistances of the several ducts; and thus, if one of these ducts be itself

an aperture in a thin plate, and its resistance therefore known, the resistance of the others can be calculated, without any direct measurement of their dimensions. This method has been employed by M. Murgue in the work already referred to for the particular case of the ventilation of mines by fans; but it seems capable of very considerable extension and very wide application.

19. We shall now give three examples of it. I. As a first instance we will take M. Murgue's case in which we have a space, S, communicating with the external air by two ducts, i and o (fig. 5), one of which, i, is a thin plate aperture, and the other duct, o, of unknown dimensions and resistance. We shall further suppose that the area of i can be altered, as, for example, by sliding shutters, indicated in the figure, and can at any time be measured, and thus its resistance calculated. To fix ideas, S may be regarded as a fairly ample fireplace, o the chimney, and i an opening in a screen in front of the fireplace; the windows of the room may be supposed open. We shall also assume that the flow through the two ducts is maintained by a *constant*[1] head, $\mathfrak{H}$. Now, referring to the phenomena described in the case of the motion of air through an aperture in a thin plate (p. 55), it will be noticed that air began to take part in the flow through the aperture as soon as it got in the rapids, and we must have a similar understanding with regard to the flow through the duct o; that is to say, if we are to be able to apply the second law of ventilation to the motion through o, the space S must be so large that the air is practically at rest, or only moving very slowly in the part between the rapids of influx at i and the rapids of efflux at o. If this condition be not satisfied the resistance of the ducts will not be independent of the flow. From the want of experimental data, we are unable to give the precise relation of the dimensions required for any given flow. Assuming, however, that S is sufficiently large, it is evident that the second law of ventilation may be applied to the two ducts i and o separately.

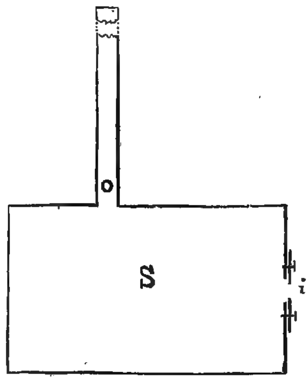


FIG. 5.

Thus let Ω be the resistance of o, $\mathfrak{H}_1$ the head between S and the top of o, and V the consequent flow.

Then $$\mathfrak{H}_1 = \Omega V^2 \quad . \quad . \quad . \quad . \quad \text{p. 59, by eq. 2*.}$$

Similarly, let A be the resistance of i, and $\mathfrak{H}_2$ the head for flow through it.

Then $$\mathfrak{H}_2 = A V^2$$

for by the first law of ventilation the flow through both ducts is the same.

Moreover, from the fact that the head for a duct is the work done upon one pound of air flowing through it, it follows that the sum of the heads for the two ducts is the whole head for the system, or

$$\mathfrak{H}_1 + \mathfrak{H}_2 = \mathfrak{H}$$

From which[2] we get

$$\mathfrak{H} = (A + \Omega) V^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

[1] This would be the case with a ventilating-fan, and approximately so with a fire-draught, but not strictly so in that and some other cases. If, however, the alteration of head can be calculated, this does not affect the principle of the method under consideration.

[2] Or, in words, the sum of the resistances of two separate ducts is the resistance of the whole, regarded as a single duct.

But further, suppose that the area of i is altered by sliding the shutters so that its resistance becomes A' and the flow through the system V'.

Then, since $\mathfrak{H}$ remains the same, we get another equation similar to (3),

$$\mathfrak{H} = (A' + \Omega)\,V'^2;$$

whence
$$(A + \Omega)\,V^2 = (A' + \Omega)\,V'^2$$

But V and V' can be measured by the air-meter described below, and hence may be regarded as known quantities, and so are the resistances A and A'; and consequently we can calculate the value of Ω, for it is equal to $\dfrac{A'\,V'^2 - A\,V^2}{V^2 - V'^2}$.

It is also evident that when Ω has been thus determined, the head $\mathfrak{H}$ and the partial heads $\mathfrak{H}_1$ and $\mathfrak{H}_2$ can likewise be calculated, and thus all the elements of the system of ventilation deduced, from observations of the measurement of flow and the area of the adjustable aperture in the thin plate denoted by i in the figure. The resistance of the duct o being thus determined, the area of its equivalent orifice is easily deduced by the equation of p. 58.

As an example of the calculation of the resistance and equivalent orifice of a chimney by this method, we may quote from some observations made upon a chimney in the Cavendish Laboratory, Cambridge. The chimney has no firegrate, but gas was burned in it to produce a head; the front was covered by a wooden screen, and the openings denoted by i were represented by circular areas cut in millboard. Two of the observations were as follows:

Area of i	·098 sq. ft.	Flow ·842 cub. ft. per sec.
,, i'	·294 sq. ft.	Flow 1·62 cub. ft. per sec.

From which we obtain

resistance of chimney = ·88
equivalent orifice = ·205 sq. ft.

The actual area of section of the chimney at the lowest part is ·875 sq. ft., so that the friction of air against the sides, and bends in the chimney reduce the effective area to about one quarter of the measured cross-section.

From the same results we get—

The total head $\mathfrak{H}$=6·6 foot-pounds per pound of air, which is approximately equivalent to a pressure of one-tenth of an inch of water; and the partial heads $\mathfrak{H}_1$ and $\mathfrak{H}_2$ can be similarly determined.

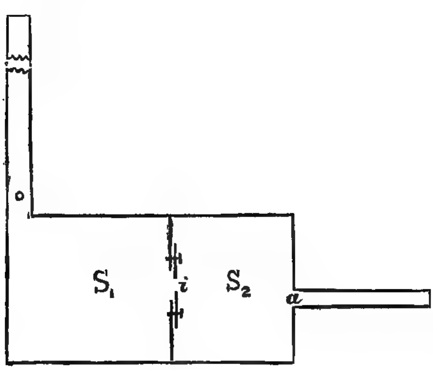


Fig. 6.

II. The next example of the application of this method is but a slight modification of the former, and is represented by fig. 6. In this we have three ducts, represented by o, i, and a respectively, of which the adjustable opening i separates the space previously denoted by S into two parts, S_1 and S_2, and the duct a may be taken to represent the chinks of windows and doors in the absence of a special inlet. If now each of these spaces be sufficiently large for the interference of the respective 'rapids' to be disregarded, we may again treat each duct separately, and, regarding the total head $\mathfrak{H}$ as

constant, and made up of the three partial heads $\mathfrak{h}_1$, $\mathfrak{h}_2$, $\mathfrak{h}_3$, the resistance of the ducts being Ω, I, and A, we have—

$$\mathfrak{h}_1 = \Omega\ V_1^2$$
$$\mathfrak{h}_2 = \mathrm{I}\ V_1^2$$
$$\mathfrak{h}_3 = \mathrm{A}\ V_1^2$$

V_1 being the measured flow expressed in cubic feet per second. From these three equations we get

$$\mathfrak{h}_1 + \mathfrak{h}_2 + \mathfrak{h}_3 = \mathfrak{h} = (\Omega + \mathrm{I} + \mathrm{A}) V_1^2 \quad . \quad . \quad . \quad (4)$$

or the equivalent resistance of the whole system is again the sum of the resistance of its three parts. By altering the adjustable opening to i' we get another equation—

$$\mathfrak{h} = (\Omega + \mathrm{I}' + \mathrm{A})\ V_2^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where V_2 is the flow observed in the second case.

These two equations enable us to find, not Ω and A separately, but $\Omega + \mathrm{A}$. Now if A represents the resistance of the chinks &c. by which the air finds its way to the chimney when the window and doors are shut, A may be abolished altogether by setting the window wide open, and Ω determined as in the first example; then, having found Ω and $\Omega + \mathrm{A}$, we can determine A, the resistance of the chinks.

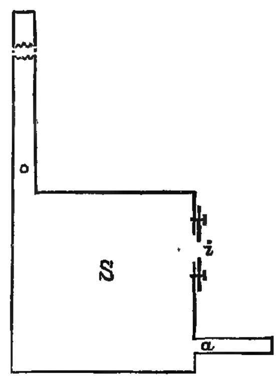


FIG. 7.

III. The third example of the indirect method of determining the resistance of ducts is represented in fig. 7, and illustrates the case of what may be called parallel orifices. In this case three ducts, o, i, a, all open directly into the space S.

We have drawn the duct a horizontal in order to indicate that no head is produced by it, as might be the case if it were vertical and there were any temperature differences. We may accordingly assume that the head is the same for the two ducts i and a, and, supposing that the whole head $\mathfrak{h}$ is made up of the partial heads $\mathfrak{h}_1$ and $\mathfrak{h}_2$, and that Ω, A, and I represent resistances, we get the following equations :

$$\mathfrak{h}_1 = \Omega\ V_1^2$$
$$\mathfrak{h}_2 = \mathrm{I} v_1^2 = \mathrm{A} v_2^2$$

where v_1 and v_2 are the parts of the whole flow V_1 passing through i and a respectively.

But by our first general law

$$V_1 = v_1 + v_2$$

hence

$$\sqrt{\mathfrak{h}_2}\left\{\frac{1}{\sqrt{\mathrm{I}}} + \frac{1}{\sqrt{\mathrm{A}}}\right\} = V_1$$

or

$$\mathfrak{h}_2 = \left\{\frac{1}{\sqrt{\frac{1}{\mathrm{I}}} + \sqrt{\frac{1}{\mathrm{A}}}}\right\}^2 V_1^2 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Whence we get—

$$\mathfrak{h}_1 + \mathfrak{h}_2 = \mathfrak{h} = \left\{\Omega + \left(\frac{1}{\sqrt{\frac{1}{\mathrm{I}}} + \sqrt{\frac{1}{\mathrm{A}}}}\right)^2\right\} V_1^2. \quad . \quad . \quad (7)$$

Equation (7) represents the relation between $\mathfrak{H}$, Ω, I, A, and V_1 of which I and V_1 are known. If the area of i be altered, a fresh equation is obtained, and so by determining the flow corresponding to three separate values of the area i, we obtain three equations from which we can determine the resistance of the ducts A and Ω and the total and partial heads.

This example illustrates a practical method of determining the resistance of the chinks in doors and windows by providing an additional adjustable and measurable aperture. It is, however, liable to serious disturbance from the effects of wind.

It should be noticed that equation (6) is an example of a general law, easily proved on the same line of reasoning, viz. :—

LAW 3. That when two or more ducts are parallel and themselves produce no head, their effect is the same as that of a single duct whose equivalent orifice is equal to the sum of the equivalent orifices of the separate ducts.

We have already seen in the two previous examples instances of the application of the law holding in the case of the ducts through which air flows successively, or ducts 'in series,' as they may be called for the sake of clearness. We repeat it here as—

LAW 4. The resistance of any number of ducts in series is the sum of the resistances of the separate ducts, provision being taken for the non-interference of their rapids.

In a subsequent chapter we shall endeavour to show how these four laws can be applied to the explanation of some important problems in ventilation.

Calculation of the Resistance of an Air-duct from its Shape and Dimensions

20. In the previous section we have shown how the resistance of an air-duct can be determined indirectly by a method which practically compares the resistance of the duct with that of a measured aperture in a thin plate; we now proceed to consider the calculation of the resistance, by means of tabulated data, from the specification of the shape and dimensions of the duct, and the nature of the materials of which it is constructed. As the basis of calculation we take the results of experiments upon the flow of air through ducts of measured size and shape, principally derived from Peclet's 'Traité de la Chaleur,' vol. i.

The practical difference between the two methods amounts to this—that in order to employ the former the duct must have been actually constructed, whereas for the latter we require only the architect's specification of the work for it; and therefore it follows that, while the former method is the one most easily applicable, and probably most accurate, for the purpose of criticising a system of ventilation already in existence, and in correcting the data employed in and checking the results predicted by the latter method, this latter must be solely relied upon in designing a system of ventilation to satisfy certain specified requirements. We have already seen that we can express the motive force which propels or draws the air along a duct by specifying the head, that is, the amount of work which is required to be done upon each pound of air during its passage; and we have also remarked that, in the case of any duct, part only of this work is spent in producing the velocity with which the air traverses the duct, and the rest is wasted in friction in various ways, and we have represented the relation between the head $\mathfrak{H}$, and the flow V, by an equation (p. 59) $\mathfrak{H}=(a+b+c+d+\ldots)\,V_1^2$ when the factors $a, b, c, \ldots$ refer to the waste of head by friction in the

various ways. We now wish to justify this equation and to express the various losses of head in terms of the dimensions of the duct.[1]

In order to fix our ideas as to the elements which have to be considered in the problem, let us represent by A B C D E F (fig. 8) the duct employed to convey air from the space R to the space O; and let us suppose that, under the action of a head $\mathfrak{H}$, V cubic feet of air enter the duct at A every second. If we can neglect changes in the density of the air, the flow as measured in cubic feet across every transverse section will be the same.

Let us examine a little more closely the motion of the air in the various sections of the duct, so that we may appreciate the various causes of waste of energy. As the air prepares to leave the space R, rapids are formed about the opening A, and the lines of motion of the air converge and cause a contraction of the effective orifice. A short distance within the tube A B, the jet of air reaches its minimum section, and the motion is parallel to the sides of the tube. From this section the jet gradually expands until it fills the whole tube at the section x.

From the orifice A to the section x the jet of moving air occupies only a portion of the cross-section of the duct; the rest is occupied by air which is

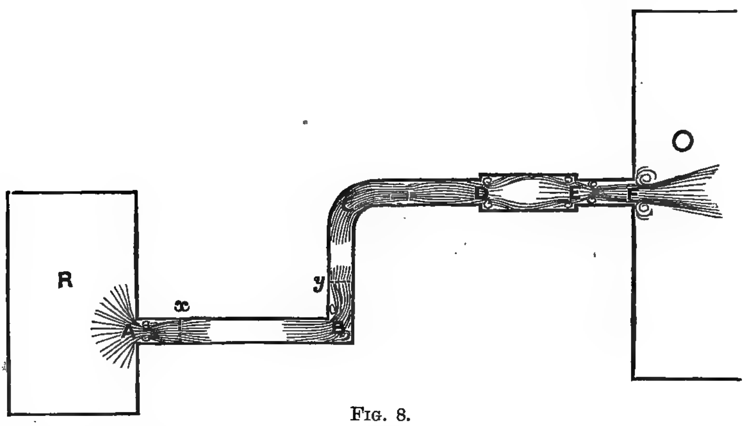


FIG. 8.

maintained in a continual state of whirling or eddying motion by the friction with the undefined boundary of the moving jet. The friction of the eddies produces heat, and here we have, therefore, the first portion of energy wasted, viz. that which is converted into heat in the rapids and eddies about the orifice A.

From x to near B, the motion of the air is parallel to the sides of the duct, and here there is loss, due to the friction of the air against the sides. Work is again spent in the friction and converted into heat. For the sake of clearness we distinguish this loss as loss by air-friction, although it may not be really different in its nature from the loss in the rapids; it depends, however, on the nature of the surface and on the length and internal girth of a straight duct. It is, moreover, distinct, in the sense that it is quite unavoidable, for we cannot have a duct without sides, whereas we can avoid abrupt changes of shape and abrupt bends.

The air is now supposed to have reached the rectangular bend B where it has to change the direction of its motion; but its inertia causes it to impinge upon the further side of the portion B C, and another contraction of the jet takes place, leaving a portion of the area occupied by eddies, and likewise the part in the angle at B. After the contraction, which takes place

[1] For full details of this part of the subject see Peclet, *Traité de la Chaleur*, vol. i. 1878; or Morin, *Études sur la Ventilation*, vol. i. chap. iv. 1863.

just after passing the angle, the jet again spreads out and fills the tube at some section y. Again we have a loss of energy in the friction of the eddies, which we may call the loss of energy due to a rectangular bend in the duct. From the section y the motion is again parallel to the sides of the duct, and the air passes on, losing energy only by friction, until the curved bend C is reached, on the further side of which we have another contraction of the jet and further loss in eddies. We need not continue the minute description of the motion; there will be losses of energy in eddies at D when the area of the duct is suddenly increased at E, when the area is suddenly diminished, and eddies are also produced at the orifice of emergence F, between the issuing jet and the surrounding air. Finally, the air issues from the orifice at F with a velocity which can be calculated from the flow and the area. The work which is required for all these operations is derived from the agent (engine or furnace chimney) which maintains the head. Hence we may suppose work done in maintaining the head as distributed into the following items :—

a. Work spent in friction of eddies at orifice of entry.
b. ,, ,, ,, a rectangular bend.
c. ,, ,, ,, a curved bend.
d. ,, ,, ,, a sudden enlargement.
e. ,, ,, ,, a sudden contraction.
f. ,, ,, ,, at orifice of exit.
g. ,, ,, against the sides of the duct when the section is uniform.
h. ,, generation of the velocity of the air at the orifice of exit.

If we can express the work spent in each one of these items corresponding to the flow of 1 lb. of air through the duct, we may take the head as numerically equal to the sum of the separate items.

It must of course be understood that the duct we have described, although it contains a number of points of interest, is still, comparatively speaking, regular in form, and is only an approximate representation of a real duct.

Let us now consider the magnitudes of the different items—

(*a*) *Loss of head at orifice of entry*

This, for unit weight of air passing, can be expressed by slightly altering a formula[1] of M. Peclet (*op. cit.* vol. i. p. 154), as $\frac{1}{2\times 32\cdot 2}\left(\frac{1}{m^2}-1\right)\frac{V^2}{a^2}$, where V is the flow in cubic feet per second,[2] a the area of the section, and m is the coefficient of contraction of the orifice which has the value ·728 when the duct is as drawn in the figure. The coefficient depends on the form of the orifice. By making the entrance into the duct trumpet-shaped, the loss under this head can be entirely avoided.[3]

[1] We have expressed the losses throughout in terms of the square of the flow. M. Peclet expresses them in terms of a quantity p, which is related to the air-velocity v, by the equation $v=\sqrt{2gp}$.

[2] To avoid complexity, we shall assume the air to remain of the same density throughout the duct. If this assumption be not admissible, the losses under the different heads should be expressed in terms of the *weight* W of air flowing per second ; the formula in this case becomes $\frac{1}{2\times 32\cdot 2}\left(\frac{1}{m^2}-1\right)\frac{W^2}{a^2\Delta^2}$, Δ being the density of the air at the section referred to. Corresponding changes would be required in each successive item.

[3] For the effect of different-shaped mouthpieces, see Peclet, vol. i. chap. iv.

(b), (c) Losses at bends

For bends made by the junction of two straight tubes, Peclet (*op. cit.* vol. i. p. 209) gives the formula $\frac{1}{2\times 32\cdot 2}\sin^2 i \,.\, \frac{V^2}{a^2}$ when i is the angle between the two consecutive portions of the duct as indicated in fig. 9. The formula [1] is applicable to angles between 20° and 90°. For still larger angles, the proper value of the loss of head is uncertain; for smaller angles, the bend may be

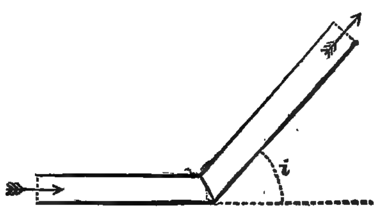


FIG. 9.

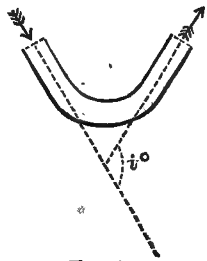


FIG. 10.

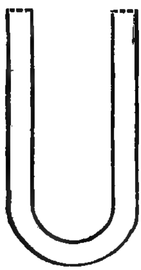


FIG. 11.

FIG. 12.

more accurately treated as if it were a curved bend. For such Peclet says that the formula for the loss of head $\frac{i^\circ}{180^\circ}\times\frac{1}{2\times 32\cdot 2}\times\frac{V^2}{a^2}$ is satisfactorily confirmed by experiment, i° being the angle through which the duct is bent from the continuation of its original direction, as shown in fig. 10. Comparing the formulæ for angular and curved bends, it appears that for the same flow the loss of head for a curved bend of 180°, as in fig. 11, is only one half of that for the same flow with two rectangular bends, as in fig. 12, producing the same effect in respect of change of direction.

(d) Loss of head at a sudden enlargement

This is not easily expressed. Peclet (*op. cit.* vol. i. chap. vii.) gives the formula for cylindrical ducts $\left(-B+1-\frac{D^4}{D_1^{\,4}}\right)\frac{V^2}{2\times 32\cdot 2\times a^2}$, where D_1 is the diameter of the larger part, D that of the smaller part, and B is a quantity which likewise depends on the ratio of the diameters and has a maximum value ·47 when the ratio of the diameters is ·6 : 1.

(e) Loss of head at a sudden contraction

This is the same as the loss which takes place at the entrance of a duct provided with a cylindrical mouthpiece of greater area than that of the duct. The loss may be represented by $\left(\frac{1}{\phi^2}-1\right)\frac{V^2}{2\times 32\cdot 2\times a^2}$, a being the area

[1] See Parkes's *Hygiene*, p. 191, according to which the velocity in a bent pipe is to that in a straight pipe as $1 : 1+\sin^2\theta$ between 0° and 90°, or $\frac{1+\cos\theta}{2} : 1$ between 0° and 180°.

of the narrowed portion, where ϕ is a contraction-coefficient varying between ·83 and unity as the ratio of the diameters changes from ·1 to 1.

(*f*) *Loss of head at the orifice of discharge*

When the duct terminates by a straight portion as in the figure (fig. 8), there is practically no appreciable contraction of the orifice, but the flow for a given head is affected by the mouthpiece with which the tube terminates. The effect of different orifices is discussed by Peclet, *op. cit.* vol. i. p. 184. (i.) When the duct is terminated by a cylindrical tube, of diameter narrower than that of the duct, we have a loss of head $\left(\frac{1}{\phi^2} - 1\right)\frac{V^2}{2 \times 32{\cdot}2\,a^2}$ where a is the area of the narrow tube, and ϕ is a coefficient of contraction similar to that given above under (*e*). (ii.) When the duct is terminated by a converging conical orifice, the loss of head is represented by the same formula, a being the area of the narrow end of the cone. The following table gives the value of ϕ and $\frac{1}{\phi^2} - 1$ for different angles of the cone.

TABLE IV.

Angles	Values of ϕ	Values of $\frac{1}{\phi^2}-1$	Angles	Values of ϕ	Values of $\frac{1}{\phi^2}-$
0°	1·00	0·00	100	0·80	0·56
10	0·97	0·06	120	0·75	0·78
20	0·93	0·16	140	0·73	0·88
30	0·89	0·26	150	0·71	0·98
40	0·86	0·35	160	0·69	1·10
60	0·83	0·45	170	0·67	1·23
80	0·82	0·49	180	0·65	1·366

(iii.) When the duct ends in a divergent cone or a trumpet-shaped orifice, the flow is somewhat improved, provided the angle of the cone is less than 50°. The maximum effect is produced when the angle of the cone is 7°. Details as to the numerical values are given in Peclet, *op. cit.* vol. i. p. 187.

(iv.) When the orifice is covered by a grating, we have a mouthpiece whose area is equal to the sum of the areas of the spaces of the grating, and whose coefficient of contraction lies between the coefficient for an aperture in a thin plate ·65 and the coefficient for a cylindrical mouthpiece ·83. The effective area of a grating can be considerably increased by bevelling the grating on the side *from* which the air flows.

(*g*) *Loss of head due to friction against the sides of a shaft of uniform section*

If we suppose a straight shaft made up of successive short tubes or rings, R_1, R_2, R_3, R_4, fig. 13, each one foot in length, the effect of the frictional

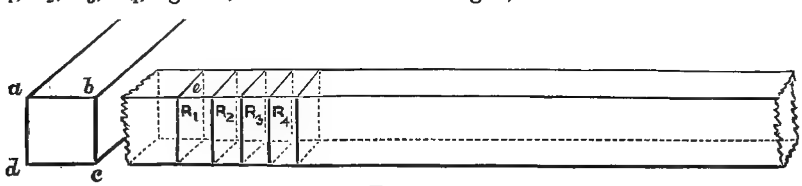


FIG. 13.

resistance offered by the sides of the shaft to the flow of air along it may be represented as a force acting upon the air contained in each ring and proportional in magnitude to the area of contact, i.e. the length of the ring e, multiplied

by the perimeter $a\,b\,c\,d$, or girth, of the internal section of the shaft. For a shaft of circular section, radius r, the perimeter is $2\pi r$; for a rectangular tube, $2\,(a+b)$. The force also depends upon the velocity of motion of the air in a manner which is at present somewhat obscure. If the flow is very slow, the resistance is approximately proportional to the velocity; but, if the velocity exceeds six inches per second, the relation between the force of resistance and the velocity is more nearly represented by the assumption that the frictional resistance varies as the square of the velocity. The resistance may also be assumed to be proportional to the density of the moving air. The force in lbs. weight acting upon a ring at which the velocity of motion is v will therefore be

$$\mathrm{F} = \frac{\beta\,\mathrm{S}\,v^2\,\Delta}{g},$$

where S is the perimeter of the section of the shaft,
Δ the density of the moving air,
g the acceleration of gravity, 32·2 feet per second,
β a constant which must be experimentally determined;

it depends upon the nature of the surface of the shaft, being very largely increased if the surface is roughened.

The work done by this force in one second is Fv foot-pounds, and this corresponds to the passage of W lbs. of air; hence the work lost in friction on the passage of one pound of air through the ring, or loss of head for each ring, is

$$\frac{\mathrm{F}\,v}{\mathrm{W}} = \frac{\beta\,\mathrm{S}\,v^2\,\Delta}{g}\cdot\frac{v}{\mathrm{W}} = \frac{\beta\,\mathrm{S}\,v^2\,\Delta\,v}{g\,v\,\mathrm{A}\,\Delta} = \frac{\beta\,\mathrm{S}\,v^2}{g\,\mathrm{A}},$$

where A is the area of section of the tube.

The differences of pressure which are used to produce ventilation currents are so small that we may without sensible error disregard the differences of density caused by the alteration of pressure. If we do so, the velocity in a uniform shaft will be the same throughout, and hence the work lost by friction will be the same for each ring; hence if L be the length of the pipe (i.e. the number of 1-foot rings) the total loss of head due to friction is

$$\gamma = \frac{\mathrm{L}\,\beta\,\mathrm{S}\,v^2}{g\,\mathrm{A}} \text{ foot-pounds per pound of air delivered.}$$

The relation $\frac{\mathrm{A}}{\mathrm{S}}$ is sometimes called the 'hydraulic mean radius' of the shaft. Denoting this by m, we have

$$\gamma = \frac{\beta\,\mathrm{L}\,v^2}{m\,g}$$

The value of the coefficient β is of vital importance to any problem of designing ventilation shafts; but it has not yet been fully investigated. Some experiments by M. Arson (see 'Encycl. Brit.' vol. xii. p. 491) tend to show that for cast-iron pipes β is not constant, but depends on the velocity of the air, and the diameter of the pipe [the constant ζ there employed is related to the β used by Morin by the equation $2\beta = \zeta$], and for diameters between 1·64 feet and ·164 feet varies between ·00242 and ·00606 for a velocity of 100 feet per second. M. Poncelet,[1] discussing the researches of MM. Girard and D'Aubisson, assigns the value ·0032 to β. But the value of β is liable to be very greatly increased by roughness of the surface of the shaft. Thus in brick shafts the projections of mortar and deposits of soot very

[1] Morin, *Études sur la Ventilation*, i. 181, 1863.

largely increase the coefficient, and in wooden shafts the roughness of the wood and deposits of dust are similarly effective. General Morin concludes, therefore, that until experiments furnish more accurate values for β, it must not be assumed to be less than ·01 for a chimney-shaft. Peclet, on the other hand, assigns the value ·003 for the coefficient of friction. The loss of head by friction is therefore represented by the formula $\frac{\beta L v^2}{m g}$ or $\frac{\beta L V^2}{m A^2 g}$, where V is the flow in feet per second and A the area of the section of the duct in which the friction is produced.

(*h*) Finally, we have to deal with the amount of work spent in producing the velocity of the gas. We know that the work required to produce, in a weight W, a velocity of v feet per second is $\frac{W}{g} \cdot \frac{v^2}{2}$ foot-pounds. Now if we take that section of the orifice of exit at which the motion is parallel to the sides of the duct—i.e. the end section of the duct, if, as in the figure, there is no contraction, but if there be contraction, then the contracted area of orifice—and if we represent this area by A, then if V be the flow through this orifice in cubic feet per second, the velocity of the air issuing is $\frac{V}{A}$ feet per second, and every pound which issues has this velocity. Hence the work spent in giving the requisite velocity v to every pound is $\frac{1}{2g} \cdot \frac{V^2}{A^2}$, or the head spent in producing velocity is $\frac{1}{2g} \cdot \frac{V^2}{A^2}$, where A is the final area of the orifice.

We have now expressed each of the items of expenditure of head in terms of the square of the flow, and, referring to equation (2) of p. 59, it will be found that the different terms a, b, c, d . . . are all accounted for under the divisions of the section headed by the same letters respectively. In order, therefore, to calculate the resistance of any given duct from its shape and dimensions, we have to substitute in equation (2) the proper values for a, b, c . . . as indicated under the corresponding headings, and add them together in order to obtain the resistance required.

In order to form an opinion of the relative magnitude of the different items representing the distribution of the energy of the head, let us introduce numerical values for a shaft of circular section 100 feet long and 1 foot in diameter, supposing that it has one rectangular bend and one curved bend of 90°; we will assume the coefficient of friction to be ·01.

Taking the items in order:

(*a*) Loss at orifice of entry: $\frac{1}{64 \cdot 4}\left(\left[\frac{1}{\cdot 80}\right]^2 - 1\right) \frac{V^2}{\left(\frac{\pi}{4}\right)^2} = \cdot 6 \times \frac{V^2}{64 \cdot 4 \left(\frac{\pi}{4}\right)^2}$

$\left.\begin{matrix}(b)\\(c)\end{matrix}\right\}$ No sudden changes of section.

(*d*) Loss at rectangular bend: $\frac{1}{64 \cdot 4} \frac{V^2}{\left(\frac{\pi}{4}\right)^2} = \frac{V^2}{64 \cdot 4 \left(\frac{\pi}{4}\right)}$

(*e*) Loss at curved bend: $\frac{1}{64 \cdot 4} \cdot \frac{1}{2} \cdot \frac{V^2}{\left(\frac{\pi}{4}\right)^2} = \cdot 5 \times \frac{V^2}{64 \cdot 4 \left(\frac{\pi}{4}\right)}$

(*f*) Loss at exit. (None)

(*g*) Loss by friction: (Hydraulic mean radius $\frac{1}{4}$) $\frac{\cdot 01 \times 100}{\frac{1}{4} \times 32\cdot 2} \cdot \frac{V^2}{\left(\frac{\pi}{4}\right)^2} = 8 \times \frac{V^2}{64\cdot 4 \left(\frac{\pi}{4}\right)^2}$

(*h*) Expenditure in velocity: $\frac{1}{64\cdot 4} \cdot \frac{V^2}{\left(\frac{\pi}{4}\right)^2} = \frac{V^2}{64\cdot 4 \left(\frac{\pi}{4}\right)^2}$

Adding these together get:

$$\mathfrak{h} = \left(\overset{a}{\cdot 6} + \overset{d}{1} + \overset{e}{\cdot 5} + \overset{g}{8} + \overset{h}{1}\right) \frac{V^2}{64\cdot 4 \left(\frac{\pi}{4}\right)^2}$$

$$= \frac{11\cdot 1 \times 4}{16\cdot 1 \times \pi^2} V^2.$$

From which we see that the friction of the duct is by far the most important item. The resistance comes out to be ·28, and the equivalent orifice is therefore:

$$\sqrt{\frac{1}{27 \times \cdot 28}} = \cdot 37 \text{ square foot.}$$

If the end of the shaft be covered with a grating, the bars and frame of which occupy one-half of the area of the duct, we must include an additional term (under the heading *f*), whose magnitude is $\left(\frac{1}{\phi^2} - 1\right) \frac{V^2}{64\cdot 4 \times \left(\frac{a}{2}\right)^2}$, where ϕ is about ·75, so that the term comes out $3 \frac{V^2}{64\cdot 4 \left(\frac{\pi}{4}\right)^2}$, and is of the same order of importance as the loss by friction throughout the whole tube.

Summary of Causes available to produce Motion of Air for the purposes of Ventilation. Calculation of Head in different Cases

21. In the preceding section we have seen that the motive power of any ventilating apparatus may be numerically represented by the head produced. When the head is known the calculation of the horse-power required to maintain a circulation of specified amount is simple, for we have already seen that the head $\mathfrak{h}$ is the work done in driving one pound of air through the shaft; and hence, if the apparatus is delivering W lbs. per second, the work done per second is $\mathfrak{h}$ W foot-pounds, and, taking the conventional value of a horse-power at 33,000 foot-pounds per minute, or 550 foot-pounds per second, we get for the power required to maintain the ventilation $\mathfrak{h}\, W/550$ horse-power. It may be more convenient to express the power in terms of the volume of air delivered; this will, of course, be different for air at different temperatures and pressures, and may, therefore, be different at different sections of the flow; but if Δ be the density of the air at any section in pounds weight per cubic foot, at which the volume delivered is ascertained, and V the volume in cubic feet delivered there per second, we have $W = V \Delta$, and hence the horse-power required is $\mathfrak{h}\, V \Delta / 550$.

If R be the total resistance of the ducts which convey the air to and from the room, we have from p. 59, $\mathfrak{h} = R V^2$.

To take a numerical instance: *3,000 cubic feet of air per hour being the*

amount required for efficient ventilation, for each person in a room, calculate the horse-power required to supply air, for 100 persons, assuming that the whole head for the circulation is equivalent to that due to the pressure of one-tenth of an inch of water.

The head $\mathfrak{h}$ corresponding to the assigned pressure is $\frac{\Delta'}{120\ \Delta}$ foot-pounds per pound, p. 57, where Δ' is the density of water in pounds per cubic foot, and Δ the density of air (remembering that for the purpose of calculation all lengths must be expressed in feet and volumes in cubic feet), and the flow is 300,000 cubic feet per hour, or 83·3 cubic feet per second; the required horse-power is, therefore, $\frac{\Delta' \times 83{\cdot}3 \times \Delta}{120\ \Delta \times 550}$, or, $\frac{62{\cdot}3 \times 83{\cdot}3}{120 \times 550}$, i.e. ·078 H.P.

The total resistance of the ducts necessary to supply the air, with the given head, will be $\mathfrak{h}/V^2$, which gives, $\frac{\Delta'}{120\Delta} \times \frac{1}{(83{\cdot}3)^2}$.

Taking the ratio of the densities of air and water at 1/800, the numerical value of the resistance becomes $\frac{800}{120} \times \frac{1}{(83{\cdot}3)^2}$, or ·00096.

Assuming, further, that the resistance of inlets and outlets is the same, we get the resistance of each ·00048, from which we calculate the area a of the equivalent orifice of the inlets or outlets respectively to be (by the formula of p. 58):

$$a = \sqrt{\frac{1}{27 \times {\cdot}00048}} = \frac{1000}{3 \times 12 \times \sqrt{10}} = \frac{1000}{111} = 9 \text{ sq. ft. (approximately).}$$

This example shows how large the areas of inlets and outlets must be to secure adequate ventilation on the usual basis of the amount of fresh air required, unless the head is so great as to produce very strong currents. For, if we suppose that the frictional resistance of each duct were such as to reduce its equivalent orifice to half the apparent orifice, a very moderate estimate, the total area of inlet orifices would be 18 square feet, and would require 9 ducts, each 2 feet × 1 foot in section, and the velocity of entry would then be about 4 feet per second. Such a flow is denominated in the table on p. 74 'a gentle wind.'

All apparatus for producing ventilation currents may be regarded as apparatus for producing a head. We shall, therefore, now proceed to consider the different ways in which the head can be produced, and, as far as possible, estimate numerically the head produced under given conditions. We shall include the natural agents of ventilation with the artificial apparatus, in order to obtain a general view of the causes which serve to produce ventilation. We defined ventilation as the continuous replacement of air; but, in order to include a case of change of air in nearly closed spaces, such as wells, closed cesspools, and such-like, we shall strain the definition and include in this survey all causes of change of air, whether continuous or intermittent. We shall group these causes under the following headings:

(*a*) *Variation of barometric pressure and of temperature. Intermittent ventilation of enclosures.*

(*b*) *Direct impact of wind upon an opening.*

(*c*) *Wind blowing across the orifice of a duct. Ventilation by steam-jets.*

(*d*) *Head produced by ventilating-fans.*

(*e*) *Head produced by blowing engines.*

(*f*) *Head produced by hot air or smoke in flues.*

Before going further, it may be well to remark that, as far as the motion

of the air in ducts is concerned, it is immaterial whether the head is produced by diminishing the pressure at the exit end of the system or increasing the pressure at the inlet end; but the difference between the two cases is of practical, if not of theoretical, importance. Methods of ventilation founded on the former plan have been called 'vacuum' methods; whereas those founded on the latter have been called 'plenum' methods. The practical distinction is that in the 'vacuum' methods (1) the crevices and chinks of a system act as inlets, and (2) fresh air can be introduced directly from the outside; whereas in 'plenum' methods, the crevices act as outlets, and the air must pass through the machine used to compress it. There is thus a balance of advantages of the two methods, which will be more fully discussed in a later section. In the sections which immediately follow we shall not further distinguish between them.

(*a*) *Variations of barometric pressure and temperature. Intermittent ventilation of an enclosure*

22. Air being an expansive fluid, it must be kept in any space, which may for ordinary purposes be regarded as closed, by the pressure of the external air upon the small openings or crevices, balancing the internal pressure, and any alteration in the internal or external pressure upsetting this balance causes a flow of air through the crevices. The balance of internal and external pressure is upset by every variation of the external barometric pressure or of the internal temperature. An estimate of the amount of change of air produced by oscillations of pressure and temperature is very easily made. A fall of pressure of 1 inch causes the abstraction of 57 cubic inches of air from every cubic foot of the nearly closed space, and a rise of internal temperature of 1° F. causes the expulsion of $3\frac{1}{2}$ cubic inches. Changes of air are thus effected in wells, cupboards, cases, cellars, cesspools, and other places, even when they have no apparent openings. And similar causes produce an expulsion of air from all soils which are porous and contain a quantity of air dependent on the barometric pressure. As the air which is derived from such sources may very frequently be contaminated, this effect of barometric change ought not to be overlooked. It is more particularly referred to in Sir Douglas Galton's 'Healthy Dwellings.' One of the most striking of the effects attributable to this cause is the development of firedamp in mines during periods of low barometric pressure, to which many colliery explosions have been due. On a small scale similar developments of pernicious gases may occur in every house; and we therefore mention this instance of natural ventilation with the view merely of suggesting avoidance of its effects by the provision of a suitable arrangement for the artificial ventilation of all such enclosures as are likely to furnish a supply of deleterious air.

(*b*) *Wind blowing directly upon an opening*

23. If a space has one opening which is exposed directly to the force of wind, the pressure at that opening will be increased by an amount which depends on the velocity of the wind, and is, indeed, approximately proportional to the square of the velocity. The experiments which justify this assumption have been made upon comparatively small surfaces exposed to the action of wind; so that in applying it to the case of the pressure at, for instance, an open window we may perhaps be pushing the application further than is justified. But, in any case, the distribution of pressure upon the irregular surface presented to the wind by an ordinary house is probably so irregular that any calculation of flow from the wind must necessarily be extremely rough. It may be

useful, however, to put the value of the pressure in numbers, as we may obtain thereby at least a rough estimate of the efficiency of the wind as a ventilating agent in comparison with others. The figures in the following table of the relation between the velocity of the wind and the pressure upon a surface at right angles to its direction are given in Spon's 'Dictionary of Engineering' as taken from the Edinburgh Encyclopædia.

TABLE V.

Character of the wind	Velocity of wind in miles per hour	Velocity in feet per second	Pressure in lbs. weight per sq. foot	Equivalent height of a column of water in inches	Head in foot-pounds per pound of air transmitted
Hardly perceptible . .	1	1·47	·005	·0009519	·0635
Just perceptible . .	2	2·93	·020	·003806	·254
Gentle winds . .	3	4·40	·044	·008373	·558
	4	5·87	·079	·01332	·888
	5	7·33	·123	·023	1·53
Pleasant brisk gale . .	10	14·67	·492	·092	6·13
Brisk gale	15	22·00	1·107	·21	14·0
Very brisk	20	29·33	1·968	·368	24·5
	25	36·67	3·075	·585	39·0
High wind . . .	30	44·00	4·429	·84	56·0
	35	51·34	6·027	1·146	76·4
Very high	40	58·67	7·873	1·5	100

By way of illustration we may remark that according to the table the head required for the example of p. 72 could have been supplied by wind impinging fully on the end of the shaft with a velocity of about 7 miles per hour.

We have been proceeding so far on the assumption that the wind affects one end only of the ventilation system. Every space to be ventilated has, however, at least two openings. A room with an open window, for instance, must have other openings if the air is to pass through the room. The other openings which correspond to the exit orifice of the shaft of the problem on p. 72 we have assumed to be entirely free from the action of the wind. In practice this will hardly be the case, and what we have really to deal with is no doubt a very complicated result, namely the difference of action of the wind upon the two ends of the ventilation system. If by any fortuitous combination of circumstances the effect of the wind were the same on both ends, or, what comes to the same thing, if there were only one opening, the effect would be merely a corresponding compression of the air in the interior, provided we could leave out of account the differences of pressure at different parts of the aperture, which, however, would really cause very large replacement of air. It will, however, be instructive to consider what volume of air would be introduced by a sudden change of pressure due to wind. Let us take, for instance, the pressure due to 10 miles per hour, viz., approximately, $\frac{1}{10}$th inch of water. This would force through the opening, to bring the pressure in the interior up to the external pressure, only one 4000th part of the amount of air in the interior space. It would appear, therefore, that the smoking of chimneys in gusty weather could hardly be attributed to the action of the wind in producing increased pressure at the chimney-top, but may be due, in part at least, to the effect of the wind at the other end of the ventilation system of which the top of the chimney is the one end. In the complexity of air-currents that must be produced by the impact of the wind upon a house, the variability of the direction and magnitude of the wind-head is not by any means surprising.

(c) *Wind blowing across an aperture*

24. If, instead of being set at right angles to the direction of the wind, the aperture is so placed that the wind can pass over it without entering the duct, the effect of the wind is to diminish the air-pressure at the orifice, and so produce a current in a direction opposite to that which is set up when the wind impinges directly. This effect of air in motion is an instance of a hydrodynamical result of considerable interest and importance, and in some cases its experimental application appears at first sight paradoxical. If, for example, a tube be provided with a cup-shaped mouthpiece, and a wooden ball be placed in the cup of such a size that the ring of contact is well within the cup, then, when a rapid current of air is driven through the tube and escapes between the ball and the cup, the air-pressure in the space between the ball and cup is so much diminished that the ball will hang suspended from the tube as long as a sufficiently strong blast is maintained.[1] We may illustrate the same principle in a manner which shows its application to ventilation by the experiment described below.

Thus, when a current of air is driven into a room by means of a fan, as

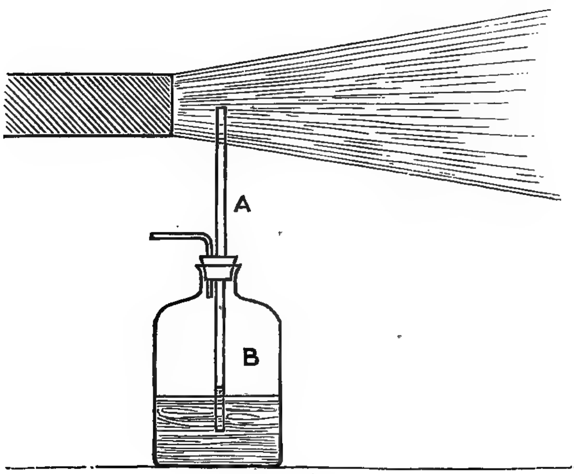


FIG. 14.

represented in fig. 14, it might be supposed that the pressure of air in the middle of the current, near the nozzle, is greater than elsewhere in the room. The precise opposite is, however, the case; the air-pressure in the current is less than elsewhere, and least where the velocity is greatest. This may be experimentally verified by introducing into the current one end of a tube A, the other end of which dips into water which is screened from the direct action of the air-current. The general plan of the experiment is represented in fig. 14. The passage of the air across the mouth of the vertical tube causes the water to rise slightly in the lower part of the tube, showing that the pressure in the current is less than that of the air of the room. The rise of liquid is exaggerated in the figure; it is of course proportional to the difference of pressure $(P - p)$ between the air in the bottle B and the interior of the current.

In some rough experiments, the velocity of the air across an open tube was

[1] This form of the well-known hydrodynamical paradox has recently been brought out by an American firm as a scientific toy.

measured by means of the air-meter (p. 105), and the diminution of pressure produced was determined by finding the height to which the water rose in the tube, inclining the tube considerably in order to make the reading more sensitive. Observations were taken with four different velocities—viz. 8·7, 10·8, 13·3, and 17·8 feet per second respectively. The results show a diminution of pressure at the orifice proportional to the square of the velocity of the air; and if the relation between the head $\mathfrak{h}$ so produced and the velocity v be represented by the equation $\mathfrak{h} = k v^2$, the mean value of the constant k deduced from the experiments is ·0155. Theoretically, when the velocity of air at any point in a jet is v, the head or difference of pressure, expressed as the height of a column of air, between the point and a point of the jet where the motion has practically ceased, is given by the formula $\mathfrak{h} = \frac{v^2}{2g} = \frac{v^2}{64 \cdot 4} = \cdot 0155\, v^2$, provided we neglect changes of density of the air; so that it appears from the above experiments that the head actually produced at the end of the narrow tube there used corresponds precisely with the theoretical head calculated in the manner explained above.

There seems no reason for supposing that the effect produced by wind blowing across an orifice is anything else than the difference of pressure corresponding to that in the interior of the jet; and it may, therefore, be assumed to be the same, however the orifice may be placed with regard to the air-current, provided that it is not exposed to the direct impact of the air. Thus leaving out of account changes in the current produced by the building from which the duct leads, and assuming that the inlet of the duct is entirely protected from the wind, we may represent (in feet) the head $\mathfrak{h}$ produced as $\cdot 0155 v^2$ where v is the velocity of the wind in feet per second. So that, for instance, wind at the rate of 15 miles an hour will produce a head equivalent to the pressure of the eighth of an inch of water.

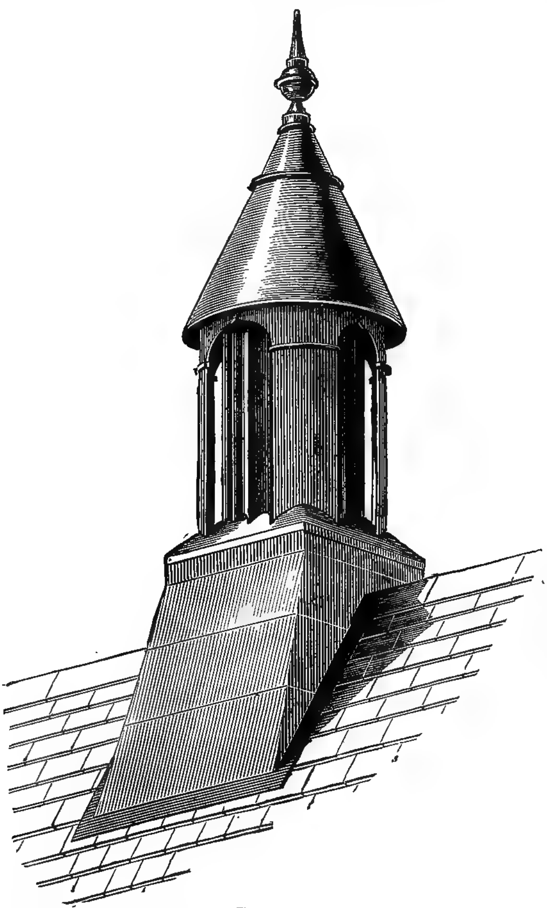


FIG. 15

The production of a head for ventilation by the motion of air over the mouth of a tube is the object of many extraction ventilators and cowls. A primary cause of uncertainty in their action when fixed to buildings is the variability in the direc-

tion of wind-currents under the influence of the surfaces of the building itself. Many forms of cowl have been designed to render the ventilators serviceable for any direction of wind, of which there are two characteristic types—viz. those with fixed vanes and those with a rotating cowl. Of the former type Boyle's ventilator (fig. 15) may be regarded as a specimen; the vanes are fixed as represented in fig. 16, so that, from whatever direction the wind may come, the

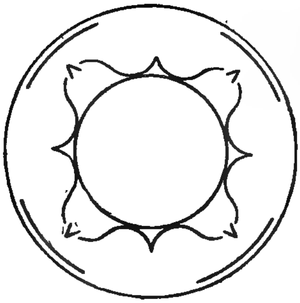


FIG. 16.

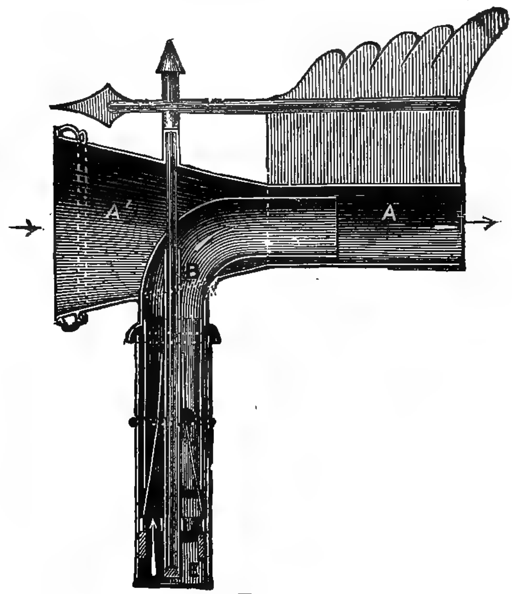


FIG. 17.

motion of the air is always tangential to the opening of the shaft; the latter type may be represented by Banner's cowl (fig. 17), which sets by means of a wind-vane so that the shaft-opening which is carried round by the wind-vane always faces away from the wind. In all forms of cowl the head is very variable, and may be very small, and is liable to be completely over-weighted by some other head. In such a case the motion of the air is reversed, and the ventilator acts as an inlet (see below, p. 101).

In order to produce a current of air along a tube, a steam-jet is sometimes directed along it. Thus at the Lower Moor Colliery, Oldham, 'an apparatus consisting of 72 vertical pipes, 5 feet long and 7 inches in diameter, was fitted to an iron frame at the top of the upcast shaft. Into each was inserted a steam-pipe having a nozzle of $\frac{3}{16}$ths inch in diameter, supplied with steam at 38 lbs. pressure. This rough apparatus exhausts 16,000 cubic feet a minute.' The forced draught of a locomotive furnace is another instance of the same kind of action. The head in these cases is due to the high velocity with which the steam issues from the nozzle, producing a considerable lowering of pressure in the neighbourhood of the orifice. An arrangement of this kind was at one time employed for the ventilation of the House of Lords, but has been abandoned. The method depends upon the same principle as the production of head by wind across an aperture, but we are unable to give any simple plan of calculating the head produced in any specified case.

(d) Head produced by Ventilating Fans

25. In order to produce a head for the ventilation of mines and large buildings, a centrifugal fan is now not infrequently used. A fan-wheel is formed by a number of vanes attached to an axle. When the wheel is

rotated air is carried along by the vanes in their motion; as the particles of air slip along the surface of the fan towards the tips of the vanes their velocity is accelerated and they finally leave the fan-wheel with a tangential velocity closely approximating to the velocity of the tips of the vanes. The general result of the rotation of the fan is a motion of air from the axis to the outside edge of the wheel, and a diminution of pressure near the axis is the result. If the wheel revolves in the open air, the air leaves the wheel tangentially at all points of the periphery, but by enclosing the fan-wheel in a circular cover with openings at the axle and a tubular aperture at the periphery, the delivery of air may be made to take place along the tube, and the effect of the fan is thereby considerably increased. The axis of the wheel is placed excentrically with reference to the circle which forms the general outline of the cover, so that the clearance between the revolving vanes and the cover gradually increases up to the tube of discharge, and by this arrangement part of the kinetic energy of the rapid motion of the air is devoted to increasing the head instead of being wasted in producing eddies in the surrounding space. Arranged in this way, the fan draws air from the apertures round the axle and throws it out by the delivery tube. According to M. Murgue[1] the most effective type of fan is M. Guibal's (fig. 18), the peculiarities of the most modern form of which are: (1) the size of the delivery aperture can be adjusted by a sliding door; (2) the aperture is provided with a trumpet-shaped mouthpiece, so that the air delivered is kept confined until its velocity is relatively small, when it passes into the atmosphere; and (3) the vanes are so shaped that they are at right angles to the periphery at their tips, but tangential to the circular aperture at the axle, so that the air slides on to the vanes without loss of energy in eddies. The theory which M. Murgue sets forth for ventilating fans enables one to see how the efficiency of machines of different types may be compared. On his view, the effective head h which a ventilating fan produces diminishes as the volume of air drawn through it increases, that is, as the area of the apertures is increased. The limiting value which the head would reach if the areas were reduced to zero (when the fan was simply maintaining a difference of pressure between the axle and the delivery tube without any air being allowed to flow through) is $\mathfrak{H}$; the difference $\mathfrak{H} - h$, or h_0, is the head required to maintain the flow through the machine itself or loss of head in the machine.

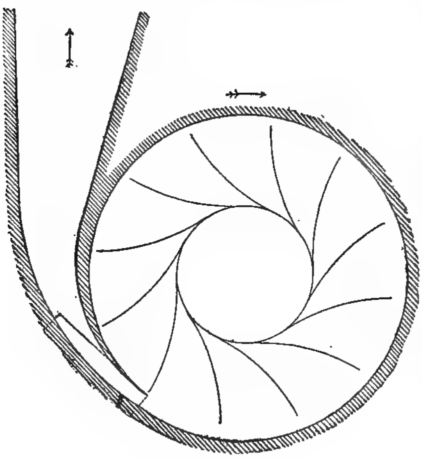


FIG. 18.

According to M. Murgue, in a perfectly designed fan, working in a cover by which the whole of the kinetic energy of the motion of the air on leaving the vanes is collected and devoted to increasing the head, the total head developed by the fan is u^2/g, where u is the velocity of the motion of the tips of the vanes—i.e. $\omega\, r$—where ω is the angular velocity of rotation of the fan wheel, and r is the radius of the vane. But in consequence of the imperfection of the fan the head developed cannot be taken as being the full

[1] *Theories and Practice of Centrifugal Ventilating Machines*, translated by A. L. Steavenson.

theoretical value, but may be put equal to $K\frac{u^2}{g}$ where K is a factor less than unity depending on the arrangement of the fan. In a fan without cover K cannot exceed ·5. The value of K is one important element in the specification of the efficiency of a fan, and can only be determined indirectly by experiments, as we shall show.

We have already seen that the flow of air through a mine, or a ventilating-shaft, or a machine, can be represented by the flow of air through an orifice in a thin plate if the area of the orifice be properly chosen. Thus, if the ventilating shaft be equivalent to an orifice, area a, in a thin plate, and h be the head required to maintain a flow of air at the rate of V cubic feet per second, we have

$$V = \cdot 65\, a\sqrt{2gh}$$

·65 being the coefficient of contraction on passing through the orifice. Now if we represent the motion of air through a ventilating-shaft as a flow through an equivalent orifice, a (fig. 19), and the motion through the fan as flow through an equivalent orifice, o, we get, if h_0 is the head required for the second orifice,

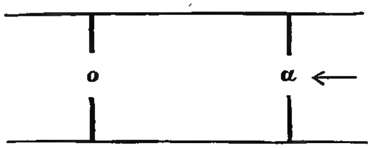


FIG. 19.

$$V = \cdot 65\, o\sqrt{2gh_0}$$

The value of h_0, the loss of head on passing through the fan, is the second important element in the determination of the efficiency of a fan. When we look into the matter further we shall see that the value of h_0 depends also upon the flow of air; and this, as we have already seen, depends on the resistance offered to the motion of the air through the mine or shaft, and hence upon the area of the orifice a, in a thin plate, which offers the same resistance to the motion. In order, therefore, to test the efficiency of a fan, we must be able to observe its effect when applied to draw air through different equivalent orifices. We may secure this by making the fan draw air, not through an actual mine or ventilation system, but into a chamber through an orifice the size of which can be adjusted to any required magnitude, each different size of orifice representing a different system. We are able to observe (i.) the velocity of air delivered by the fan, and hence the rate of flow, V; (ii.) the area of the equivalent orifice a; (iii.) the effective head h (the difference of pressure in lbs. weight per square foot between the air in the chamber and outside divided by the density of air); (iv.) the velocity of the tips of the vanes, u. Connecting these quantities, we have the following equations:—

$$\begin{aligned} V &= \cdot 65\, a\sqrt{2gh} \\ &= \cdot 65\, o\sqrt{2gh_0} \\ K\,\mathfrak{h} &= h + h_0 \\ \mathfrak{h} &= \frac{u^2}{g} \end{aligned}$$

whence

$$h = \frac{K u^2}{g\left(1 + \frac{a^2}{o^2}\right)}$$

$$V = \cdot 65\, a u\sqrt{\frac{2K}{1 + \frac{a^2}{o^2}}}$$

From observations of the magnitudes enumerated above the value of o can be found for the machine, and thence the value of K determined, as

likewise the values of h_0 and h for the different values of the equivalent orifice a. When these have been determined, the values of h and V can be represented on a diagram by curves, of which the ordinates are h and V respectively and abscissæ a. Such curves are called characteristic curves for the fan, as suggested by the Commission on Ventilation of the district of Gard. M. Murgue adds a table of the value of K (sometimes determined only to a rough approximation), deduced from the published observations upon fans of various descriptions. The values vary between ·1 for some machines without cover to ·7 for machines of the improved Guibal type. The best machines, therefore, produce a head three-quarters of the maximum possible.

26. Another method of producing by mechanical means a head for ventilation is the rotation of a wheel with inclined vanes, by which the air is made to pass transversely through the wheel parallel to the axis of rotation. The action in this case is the direct converse of the action of a windmill, and practically amounts to driving the windmill in order to produce a wind.

These machines during a revolution cut off a portion of the air from the one side of the wheel and transfer it through the wheel, the relative motion being, roughly speaking, similar to that produced by the action of a screw. In some forms the vanes are helicoidal, when the analogy is still closer. M. Murgue discusses the theory of these machines in the work already quoted, and classifies them as working by direct impulsion. The formulæ arrived at are identical in form with those given for centrifugal machines. For those discussed by M. Murgue the coefficient K varies between ·05 and ·2, so that they are much less efficient in producing head than the centrifugal machines; but for ventilations requiring a large supply of air at no considerable head they may be as effective.

The form which has been frequently applied to the ventilation of buildings is Blackman's air propeller, a sketch of which is given in fig. 20. According to the statement of the company supplying it, it gives about 12,000 cubic feet per minute per horse-power for the largest size, and about 6,000 cubic feet per minute per horse-power for the smaller sizes; but we may presume that in this case the only resistance that is contemplated is that offered by the machine itself, and the amount of air supplied through the ducts of any ventilation system will depend upon the resistance of the ducts as well as that of the machine, just as in the case of the centrifugal fan; and the essential characteristics of the fan can only be determined by the experimental method indicated above.

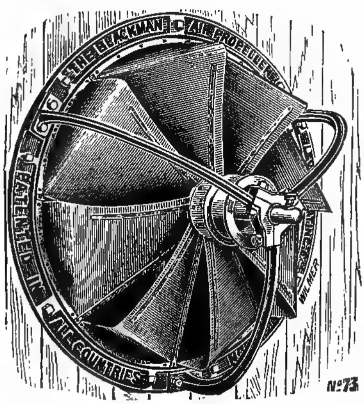


FIG. 20.

An important consideration in the matter of ventilation by fans is the question of the mechanical efficiency of the apparatus. The power used in discharging V cubic feet of air per second from a head $\mathfrak{h}$ is $\mathfrak{h}\,V\,\Delta$ foot-pounds per second, where Δ is the density of the air supplied. In calculating the mechanical efficiency of fans and other ventilating machines, M. Murgue substitutes for $\mathfrak{h}$ the theoretical head of the machine and not the effective head h, thereby including in the useful work of the machine that spent in forcing the air through the machine itself. Comparing on this assumption different ventilating-machines, he obtains the following results for the ratio of useful work done to work supplied to the machine.

Mean mechanical efficiency of ventilation by	direct impulsion[1]	·260
" " " "	centrifugal force, without cover	·278
" " " "	with cover and chimney	·467

(e) *Head produced by blowing machines*

27. A number of machines have been designed and used for supplying an air-blast to furnaces, and for ventilation, the principle of which is widely different from that of the machines which have hitherto been discussed. The simplest type may be represented as an air-pump or bellows driven by the piston of a steam-cylinder. The air-pump is simply a barrel with two valves, one opening outwards, the other inwards, with a piston sliding in the barrel. As the piston moves backwards and forwards the valves alternately open and shut, and the air is drawn in at one valve and forced out at the other. The barrel of the air-pump may be made as large as we please—provided we have power to drive it—and by arranging it like the cylinder of a steam-engine a delivery of air may be secured both by the back and forward stroke; and with several pumps on the same crank, each delivering into an air-chamber from which outlets proceed for the distribution of the air, a steady flow through the ventilation system may be obtained. Drawings and particulars of various blowing machines are given in the supplement to Spon's 'Dictionary of Engineering' (art. *Blowing-machine*), and a form specially designed for ventilation by Cunningham is mentioned in the article 'Ventilation' in the 'Encyclopædia Britannica.' One source of loss of energy in the working of these machines lies in the fact that the motion of the piston has to be reversed with every stroke, and however light the piston may be made its mass is large compared with the mass of air to be moved. The loss may be reduced by special design of the machine which drives the piston, but cannot be entirely obviated, so that for the purposes of producing a current of air a rotary piston seems much more suitable. Roots' blower, fig. 21, is a machine which is worked by rotating pistons. Two pistons, each shaped like a figure of 8, are worked on parallel axles in a box with two openings; the box is formed of two half cylinders separated by two flat portions, and in these two flat portions the holes for entry and delivery are made. As the pistons rotate the air is driven through the apparatus. Cunningham has also modified this machine for ventilation.

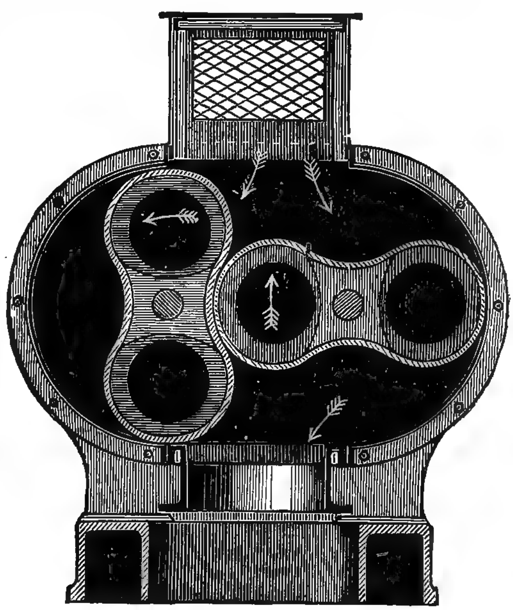


Fig. 21.

In all machines of the air-pump or rotary piston type it is evident that a definite volume of air is transmitted at each stroke. When this volume is known—and it may be calculated from the dimensions of the machine—the volume V of air transmitted per second is known from the speed of revolution, and whatever head is needed to drive that

[1] See above, p. 80.

volume will be supplied from the source of power which drives the fan. A machine of this description can therefore be tested by replacing the ventilation system by an orifice in the air-chamber whose area is known, and calculating the head required from the formula,

$$\mathfrak{h} = \cdot 65a\sqrt{\frac{V^2}{2g}},$$

and measuring V for a given speed of rotation.

The work done per second is $V\,\mathfrak{h}\,\Delta$, and if we measure the power required to drive the machine we get the efficiency, as the ratio of the effective work per second to the whole power required to drive the fan.

(f) Head produced in hot-air and smoke flues

28. In the case of a vertical hot-air flue we can calculate the head in the following manner. The hot air rises because its density is less than the density of the air surrounding the flue. Let us suppose the density of the air in the flue to be uniform throughout the flue and equal to Δ' lbs. per cubic foot, and the density of the air surrounding the flue to be likewise uniform and equal to Δ lbs. per cubic foot. Then every cubic foot of volume of air in the flue will be acted upon by a force equal to the weight of $(\Delta - \Delta')$ lbs., and hence the total force on the air in the flue is $(\Delta - \Delta')\,A\,H$ pounds weight, where A is the area of the flue and H its height. If the air is passing up the flue at velocity v feet per second $(\Delta - \Delta')$, $A\,H\,v$ foot-pounds of work per second will be done by the force. But this corresponds to the delivery of $A\,v\,\Delta'$ pounds of air; hence the head, or work-equivalent of the flue per pound of air, is $\frac{\Delta - \Delta'}{\Delta'}H$.

We notice about this expression that the head depends merely upon the density of the air inside and outside, and upon the vertical height of the flue. Though we made use of the area of the flue in the calculation, it has disappeared from the result, and we may rightly conclude that, provided the density of the air is the same throughout, the head will not depend upon the area, shape, or size of the flue, but merely upon the difference of level of the opening at the top and bottom. There may be any number of bends and constrictions and horizontal portions: these affect the resistance; they do not affect the head, except possibly indirectly, by altering the distribution of temperature and thereby the density of the air.

The difference of density is produced by raising the temperature of the air in the flue above that of the outside air either by supplying heat to the air as it passes into the flue at the bottom, as in an ordinary chimney, or by supplying heat to the air of the space to be ventilated and letting the air so heated pass into the flue, as in the case of an ordinary ventilation flue unprovided with any special supply of heat.

As the temperature of the air in the flue is much more easily measured than the density, we will express the head in terms of the temperature. We have already (§ 8) explained how the density may be calculated from the temperature. If T be the temperature of the air in the flue, and t that of the external air, in Fahrenheit degrees, $\frac{\Delta'}{\Delta} = \frac{459+t}{459+T}$;

whence we find the head,

$$\mathfrak{h} = \frac{T-t}{459+t}H \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The head is therefore proportional to the difference of temperature of the internal and external air, and the flow will be upwards if the internal temperature is greater than the external, but downwards if the reverse is the case. For the

purposes of accurate calculation the external temperature should be measured, but for very rough computation we shall not be far wrong if we assume the external temperature to be always at 41° F. and the head of a hot-air flue to be therefore $\frac{1}{500}$th part of the product of the difference of internal and external temperatures, and the difference of level of the top and bottom openings.

It follows from this calculation that any variation in the temperature of the air contained in a chimney will cause a change in the ventilation head; now the temperature in the chimney will fall if the flow of cold air into it be increased by diminishing the resistance of the inlet ducts. The head is therefore, strictly speaking, not independent of the flow, although it may be assumed to be so if the change is a very small fraction of the whole flow; thus if a large block of buildings be ventilated by one very large chimney-stack the head might be assumed to have remained constant, although the resistance of the entry inlets of one room had been doubled. If the shaft is long, a small change in the flow will not affect the temperature very much at first, for heat will be communicated from the hot sides of the chimney; but ultimately a permanent change in the flow will correspond to a permanent change in the temperature and therefore in the head. We have been of course tacitly assuming that the supply of heat has been constant; such a condition would hardly be realised with a coal fire at the foot of a chimney, but it would be so if the heat were furnished by the combustion of a number of gas jets with a constant supply of gas. In such a case we might be able to express the head in terms of the heat-supply and the flow, which can be done as follows. Let Θ be the amount of heat supplied per second, and let the flow of *cold* air to the chimney be V cubic feet per second; the weight of air warmed per second will be $V\Delta$. It is warmed at practically constant pressure, so that the specific heat is ·238, and the heat used per second is $\cdot 238\,(T-t)V\Delta=\Theta$,

from which we get (by equation 8, p. 80)

$$\cdot 238\frac{\mathfrak{h}}{H}(459+t)V\Delta=\Theta\,;$$

or

$$\mathfrak{h}=\frac{\Theta H}{\cdot 238(459+t)V\Delta}\,;$$

or

$$\mathfrak{h}V=\frac{\Theta H}{\cdot 238(459+t)\Delta}.$$

Thus the head is inversely proportional to the flow.

Let us apply this equation to calculate roughly the head due to combustion in a special case.

To find the Head of Air with an Open Gas Fire burning 20 *Cubic Feet of Gas per hour*

1 lb. of gas produces 18000 lb. F. units.

The density of coal gas is ·0418 lb. per cubic foot.

The weight of gas burned is therefore equal to $\frac{20\times\cdot 0418}{60\times 60}=\cdot 00023$ lb. per second.

T may be taken as 41° F.; and assuming all the heat to go up the chimney we have

$$\mathfrak{h}=H\,\frac{\cdot 00023\times 18000}{\cdot 238\times 500\times V\Delta}$$

$$=\frac{H}{V\Delta}\times\cdot 035.$$

In order to determine the head we require to know the weight of air passing per second, which must be determined by observation of the velocity of transmission, but if the area a of the orifice to which the chimney is equivalent be known, and likewise the equivalent area a' for the inlets, we get (see p. 61)

$$\mathfrak{H}=2{\cdot}35\left(\frac{1}{a^2}+\frac{1}{a'^2}\right)\frac{V^2}{2g},$$

and, if W be the weight of air delivered $W=V\Delta$.

Whence we get

$$W^3=\frac{2H\Delta^2 g}{\left(\frac{1}{a^2}+\frac{1}{a'^2}\right)}\;\frac{{\cdot}0036}{2{\cdot}35}={\cdot}00056\,\frac{H}{\frac{1}{a^2}+\frac{1}{a'^2}}.$$

Hence for a given quantity of gas burned per hour the weight of air carried up the chimney varies as the cube root of the height of the chimney, and as the cube root of the square of area of the equivalent orifice if the air be allowed free access to the base of the shaft, i.e. if a' may be regarded as indefinitely great. This equation may be used to determine the smallest value of a', or the area of the inlets, that is consistent with the delivery of a given weight of

Table VI.—Production of Head of given Numerical Value by Various Agents.

Head or equivalent pressure			Conditions necessary to produce the Head								
Pressure in inches of water	Pressure in lbs. weight per sq. ft.	Head in foot-pounds per pound, or height of air column in feet	Velocity of wind for direct impact in feet per second, § 23	Velocity of wind passing over mouth of duct, § 24	Velocity of tips of vanes of centrifugal fans, § 25		Velocity of periphery of wheel of direct impulsion fans, § 26		Horse-power per 1000 cu. ft. per hour by blowing engines,[1] § 27	Internal temperature of 40-foot shaft,[2] § 28	Barometric variation, § 22
					Worst	Best	Worst	Best			
·01	·052	·670	5·71	6·57	14·7	5·55	20·8	10·4	·00152	49·4	Intermittent
·02	·104	1·34	8·10	9·29	20·8	7·85	29·4	14·7	·00302	57·7	
·03	·156	2·01	9·78	11·4	25·4	9·62	36·0	18·0	·00454	63·1	
·04	·208	2·68	11·4	13·1	29·4	11·1	41·5	21·0	·00606	74·5	
·05	·259	3·35	12·5	14·7	32·8	12·4	46·4	23·2	·00757	82·9	
·06	·311	4·02	13·7	16·5	36·1	13·6	50·9	25·4	·00909	91·3	
·07	·363	4·69	14·8	17·5	38·9	14·7	55·1	27·5	·0106	99·6	
·08	·405	5·36	15·6	18·5	41·5	15·7	58·8	29·4	·0121	108·0	
·09	·467	6·03	16·7	19·9	44·1	16·6	62·3	31·2	·0136	116	
·1	·519	6·70	17·6	20·7	46·4	17·5	65·7	32·8	·0152	124	
·2	1·04	13·4	24·8	29·4	65·7	24·8	91·8	46·4	·0302	208	
·3	1·56	20·1	30·2	36·0	80·5	30·4	114	56·9	·0454	292	
·4	2·08	26·8	34·8	41·5	92·9	35·1	131	65·7	·0606	376	
·5	2·59	33·5	38·8	46·4	104	39·3	147	73·4	·0757	460	
·6	3·11	40·2	42·4	50·9	114	43·0	161	80·5	·0909	544	
·7	3·63	46·9	45·8	54·9	123	46·4	175	86·9	·106	627	
·8	4·05	53·6	48·3	58·6	134	49·7	186	92·9	·121	711	
·9	4·67	60·3	51·8	63·5	139	52·7	197	98·5	·136	795[3]	
1	5·19	67	54·5	65·6	147	55·5	208	104	·152	879	
2	10·4	134	76·6	92·9	208	78·7	290	147	·302	1720	
3	15·6	201	93·4	113·8	254	96·2	360	180	·454	2550	
4	20·8	268	109	131·4	294	111	415	208	·606	3350	
5	25·9	335	120	147	328	124	464	232	·757	4230	
6	31·1	402	131	165	361	136	509	254	·909	5070	
7	36·3	469	142	175	389	147	551	275	1·06	5900	
8	40·5	536	150	185	415	157	587	294	1·21	6700	
9	46·7	603	160	190	441	166	623	312	1·36	7600	
10	51·9	670	169	208	464	175	656	328	1·52	8400	

[1] Neglecting work wasted in the engine itself. [2] External air assumed to be at 41° F.
[3] Beyond this point the numbers have no practical value for a 40-foot shaft.

air per second through a shaft of known height in which a given quantity of gas is burning.

Having now given an account of the various means by which a head can be produced, we give on the preceding page a comparative table of the numerical results produced by the different agents. We shall so frequently employ both 'foot-pounds per pound' and equivalent water-pressure to express the head that we have thought well to include in the preceding table the numerical expression of head in both manners, assuming that the air delivered is half saturated and at 50° F. and 30 inches of mercury.

Local Circulation

29. We have now completed our discussion of the general circulation of air in a ventilation system, and have confined our attention to the motion in the ducts, where the general direction of the motion across the whole section of the duct is along the sides; we have now to consider the motion of the air in the space which the ducts are intended to ventilate. In that space the air which enters by the inlets makes its way by a more or less devious course to the outlets; if our knowledge were complete we ought to be able to predict the exact path which the air would take through the room from the inlet to the outlet, although it might be extremely involved and complicated; but, as we have already said, in all ordinary cases the air of a room is thrown by local sources of heat and other causes of motion into a state of really indescribable turmoil, and taken in detail the motion is unsteady and incalculable. All that we can do by way of calculation is to lay down some general principles which govern the circulation of air in the ventilated space, or local circulation, as we have called it. Experimentally we can do on a small scale what is habitually done on a large scale by meteorologists, and determine at any instant the direction and force of the wind at any particular point of the room, and, just as they do, we can lay down upon a chart an arrow which, by the way it points, shows the direction of motion of the air, and, by some convention as to the character of the arrows, indicate the force. But here we meet with a considerable difficulty both in the matter of experimental determination and of diagrammatic representation too. Meteorologists, as a rule, deal only with the horizontal motion and effect of wind, whereas with us the vertical motion is at least as important as the horizontal, so that we ought to be able to set our arrow in any direction whatever, and we really want a solid model for the purposes of representation.

We must, however, be content with a very incomplete and partial investigation of the local circulation, and represent the motion in horizontal or vertical sections. It will be seen that if we could have a sufficient number of direction-arrows arranged, the one to follow the other, we should be able to start from the outlet and ultimately arrive at the inlet, and, assuming that the motion in any particular part of the room has remained the same throughout the course of the investigation, we should be able to construct a curved line from the inlet to the outlet, which would indicate the direction of motion of the air at any point of its length. Such a line would be called a 'stream-line,' and a complete set of stream-lines would give a complete account of the motion of the air from inlets to outlets, provided that the motion were steady. At the inlet itself the stream-lines would evidently join on to the lines of flow of the air in the duct.

But when an air current enters a room there is a gradual interchange of individual particles between the air in the stream and the adjacent air: this results in an obliteration of the stream-lines near the boundary. The effect

is considerably increased by the friction between the moving air and the neighbouring air, which gives rise to a series of eddies, so that the motion of the air often cannot be traced as a continuous stream for any great distance from the inlet. Stream-lines are still further obliterated by the cross currents, due to local causes, such as the convection produced by sources of heat in the room. These, as we have said (§ 14), are often very numerous, and often varying, and hence we cannot hope to trace the complete path of the entering air. There are, however, some cases in which the conditions are favourable to the permanence of the currents, over a comparatively long path, and steady motion, with stream-lines of permanent shape, establishes itself in certain parts of the room. For such cases, if the air of the currents is cold, and passes across the occupants of a room, the effect is well known as a draught. A good, steady draught is a sufficient indication of steady stream-lines of cold air in the region.

30. Well-established stream-lines of hot air are also frequently formed in vertical columns and across ceilings, but as they are generally out of the reach of persons occupying the rooms, or are not so markedly unpleasant as cold currents, they are less generally noticed.

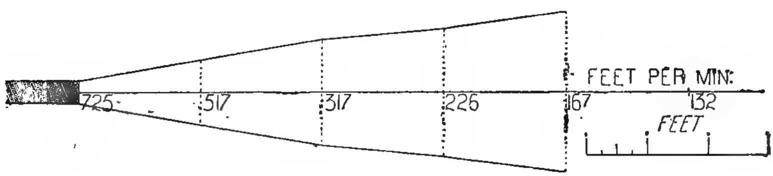


FIG. 22.

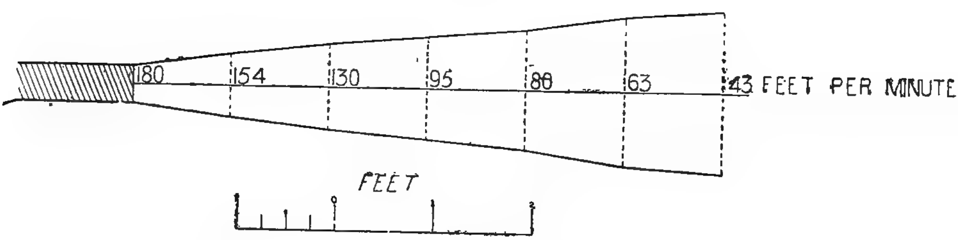


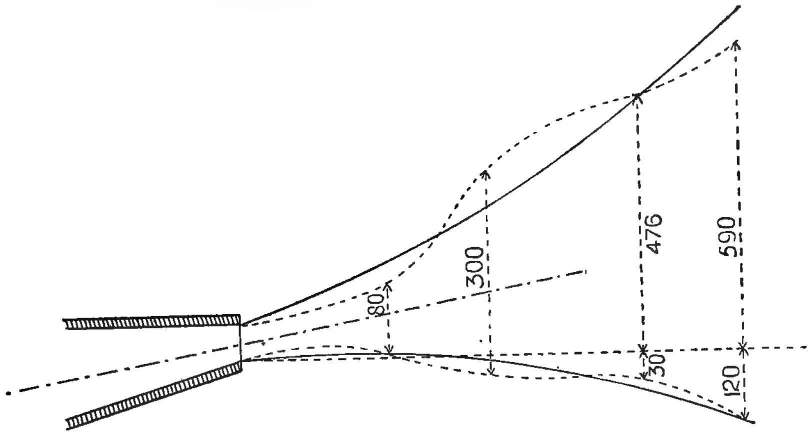
FIG. 23

Stream-lines can, moreover, generally be traced in the immediate neighbourhood of inlets and outlets. In speaking of air-ducts we have given the name of rapids to that part of the jet, either issuing or emergent, where the motion is very considerable. We can, therefore, trace the stream-lines for the rapids, and the main use of this tracing will be to indicate the limits of the rapids.

In order that the reader may form for himself an accurate idea of the extent of the rapids formed by a current of air issuing into a room as it spreads out from the orifice under the influence merely of its own motion, we have made two diagrams drawn to scale (figs. 22, 23), from measurements upon actual currents generated by a 'Cyclops' rotary fan in a large room, showing the boundary line on each side of a horizontal section of the current and the velocity of air at the core. The currents were delivered through a short straight cardboard tube about fourteen inches long. It will be noticed that the current with the higher velocity has a wider angle of spread at the nozzle, and the velocity in the core falls off more rapidly in the stronger than with the slower running current. The general shape of the stream-lines in

the rapids can easily be inferred from the direction of motion at the orifice and the extent of the rapids.

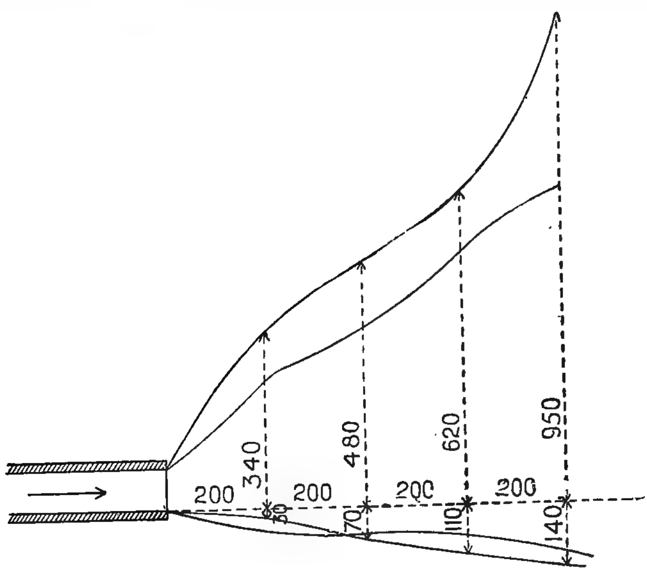
The energy of the motion of the issuing air is more dissipated in eddies



SCALE 1/9

FIG. 24.

if the velocity of entry be greater, as the diagrams indicate, thus a rapid current of air will cause more complete mixing with the air in the room than the slow delivery of the same quantity of air through a larger opening; but,



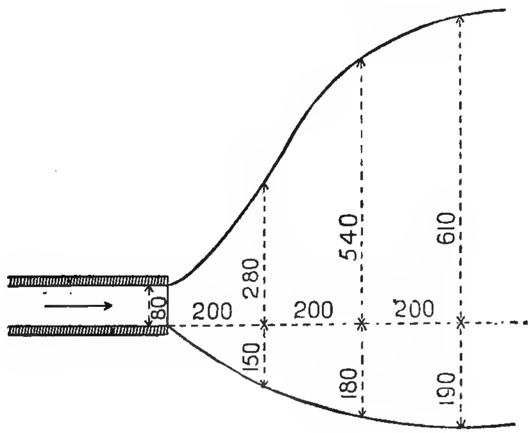
SCALE 1/15

FIG. 25.

on the other hand, the greater velocity means a much more definite current for a short distance, and hence may cause unendurable draughts, whereas the slow delivery may cause more widely extended draughts, which though unpleasant are not classed as unendurable.

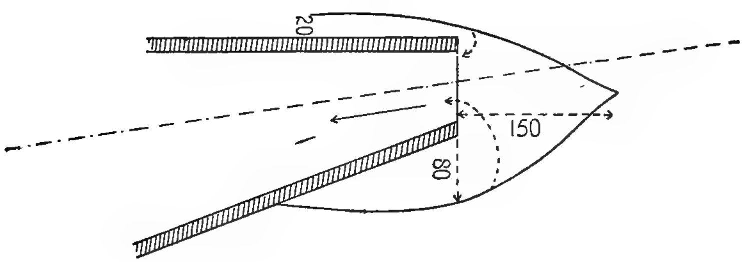
We have reproduced, also, three diagrams of inlets (figs. 24, 25, and 26),

and one of an outlet (fig. 27), by General Morin (Etudes, ii. pp. 184–188), representing, in vertical section, the extent of the rapids for two orifices of entry, and one orifice of exit respectively. In figs. 24 and 27 the orifice represented is the same, a rectangular opening eleven feet by three inches. The velocity of entry in fig. 24 is about six feet per second, and in fig. 27 the velocity of exit about 7·5 feet per second. The observed dimensions of the stream are figured on the drawings in millimetres. The dotted line of boundary of fig. 24 shows the observed extent of the vertical section of the entering stream, within which the velocity is sufficiently great to affect an air-meter, that is, not less than 5·5 inches per second. The full line indicates the same boundary with the irregularities of observation smoothed out. The



SCALE ⅟₁₅

FIG. 26.



SCALE ⅕

FIG. 27.

boundary line in fig. 27 similarly indicates the limit beyond which the air-meter ceases to show a current.

Figs. 25 and 26 represent vertical sections of streams of air issuing from a rectangular opening four feet wide by three inches high. The boundaries of the stream were determined by the use of a candle flame. Fig. 25 represents two streams, the wider issuing at the rate of 3·3 feet per second, the narrower at two feet per second. The dimensions of the former are figured on the drawing in millimetres. Fig. 26 represents the vertical section of a stream issuing from the same orifice as the preceding at the rate of 2·4 feet per second. The issuing air in all these cases was cold. Compared with the streams represented in figs. 22 and 23, the widening out at a short dis-

tance from the orifice is very marked, and is to be attributed to the orifice being long and narrow instead of being cylindrical.

31. We shall attempt to give in figs. 28, 29, and 30 some actual examples of stream-lines drawn, or rather inferred, from observations of the vertical motion of air, so as to give the reader a general idea of what the motion of air would be in any special case of ventilation that he may have to deal with. In general character, the problem is the same as the determination of the flow of water in corresponding cases; and the reader may, perhaps, be helped to realise the actual state of the motion of the air in any special case if he will consider what the distribution of currents would be if water were the fluid he were dealing with instead of air. The permanence of slow currents of water through water can be shown experimentally if the flowing water be slightly coloured, and there is little doubt that analogous cases of the flow of air through air could be exhibited if the flowing air could be as easily identified as coloured water. An obstacle in the way of a current of air promotes the formation of eddies and consequent mixing, especially if the flow is rapid; if the flow is slow, however, a steady current may establish itself round the obstacle.

In order that the effects of the flow may be freed from disturbance on account of its different density the entering air must be at the same temperature as that into which it flows. This is, however, seldom practicable, and we must deal with cases of flow into relatively warmer or colder air. In such cases a horizontal current will be deflected downwards or upwards, as the case may be. A current of warm air directed vertically upward will extend further, and a corresponding current of cold air will be less extensive, and, *vice versâ*, when the direction of the current is vertically downward. An orifice for the admission of cold air in the ceiling of a room slightly warmer than the entering air affords a very good instance of permanent stream-lines continuing to the table or floor underneath the opening. In a large hall or church, a lantern tower with large area of windows may produce near the floor below it, on a cold day, a descending current which very clearly exemplifies the steadiness of flow for a considerable vertical distance; the effect produced on those sitting below is that of a cold down-draught, not attributable to open windows, but to the cooling effect of the windows on the air of the tower. A similar effect may frequently be observed at the sides of churches with clerestory windows. A row of hot-water pipes along the central passage of the church produces an oppositely directed current of warm air; the circulation is completed by a cold air current along the floor and an opposite current along the ceiling. The course of the currents is represented by arrows in fig. 28. The result of such an arrangement will therefore be that a large

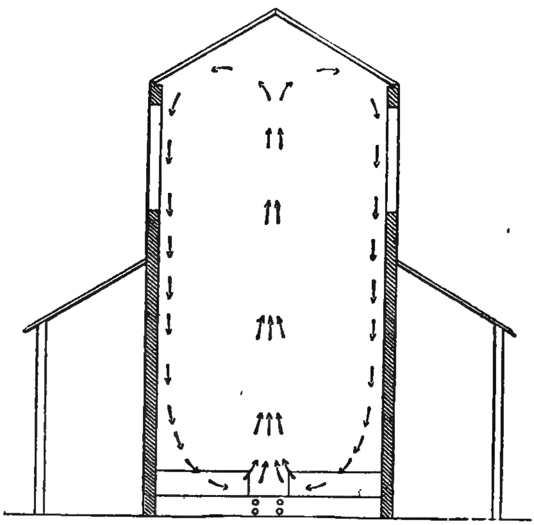
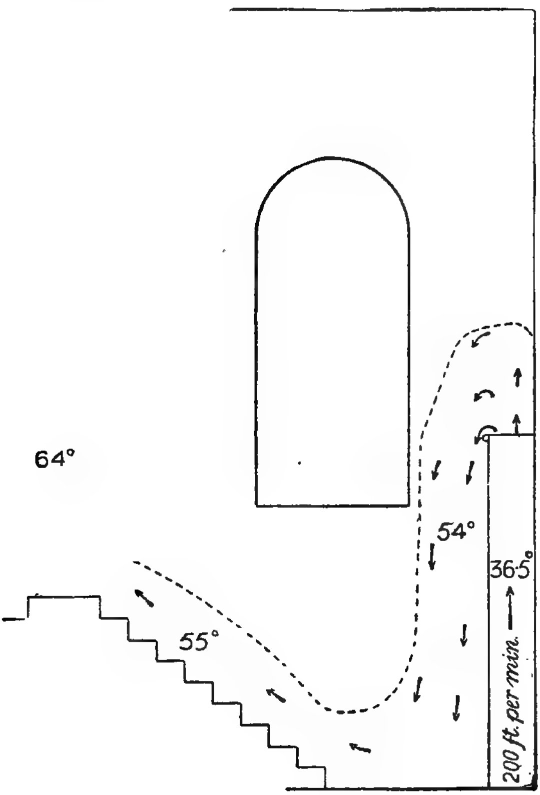


FIG. 28.

part of the heat of the pipes will pass through the glass of the windows without producing any effect in raising the general temperature of the building.

In the case figured the currents are not due to the introduction of fresh air from outside, but to the circulation established in the interior of the building. In introducing fresh cold air it is extremely difficult, if not impossible, to prevent cold currents in the lower parts of the building. With the object of avoiding such currents the incoming fresh air is directed upwards either by a Tobin tube (see fig. 29) or a Sherringham inlet, or, more simply, by leaving an open space between the upper and lower sashes of the windows; but if these expedients be primarily successful in mixing the incoming fresh air with some of the warmer air of the room we still get a



SCALE 3/16 in. to 1 foot

Fig. 29.

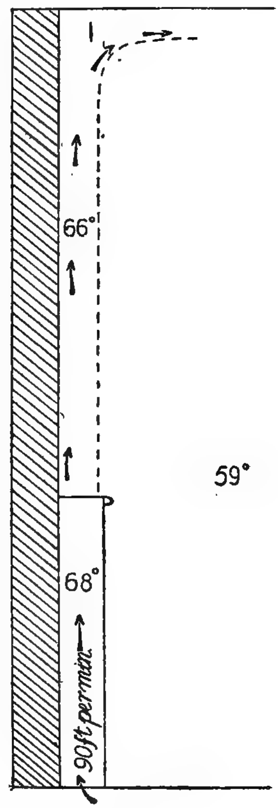


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Fig. 30.

reservoir of air near the ceiling (round the opening) considerably colder than the air of the rest of the room, and the next stage of the problem may be stated thus: Certain outlets have to be supplied and the air has to be moved from the cold regions (near the inlets) to the outlets; what will be the distribution on the floor? The best answer that can be given is that the colder air will make a very short journey to the floor, and will then move along the floor towards the outlets if they are near the floor; if, however, they are near the ceiling, a layer of cold air will lie on the floor until part of it is warmed sufficiently to rise to the outlets.

Warm air delivered into a room will behave in just the opposite way: if it is directed upwards it will make its way direct to the ceiling; if directed

downwards, the flow in that direction will soon be stopped, and a reservoir of air formed, warmer than the rest, and from this warm reservoir air will rise to the ceiling and there form a warm layer.

In order to illustrate the motion of the air in these two typical cases I have investigated experimentally, by apparatus described in a subsequent chapter, the flow of air from two Tobin tubes, one delivering cold air and the other warm air, and plotted the distribution of flow for the two cases in figs. 29 and 30. The figures are, of course, only rough approximations, but they are drawn to scale so as to give an idea as to how far the motion extends in the two cases. The boundary of the stream of air is represented by a dotted line, and the direction of flow by arrows; the velocity in the tube is indicated, as well as the temperatures in the tube, the stream, and the air of the room.

APPLICATION OF THE FOREGOING PRINCIPLES TO SPECIAL CASES

32. In discussing the principles of ventilation we have analysed the process into 'General Circulation' (§§ 15–28), and 'Local Circulation' (§§ 29–31), and have considered separately the effect of different characteristic conditions. The application of the principles will be made clearer if we take some specific instances. We will arrange them in order of simplicity.

1. Closed Room with Heating Apparatus

33. Let us first suppose that we have a room which, during its occupation, has no opening except unintentional crevices, and which is warmed by a gas stove without chimney, or by hot-water pipes along the floor on one side. It is provided with windows which we suppose to be shut. From the point of view of ventilation such a room, of course, borders on the impossible, but there can be few people who have not had to spend some hours, at any rate, in rooms of which the above is a fairly accurate description.

Here we have to deal with local circulation only. General circulation does not exist to any large extent; enough fresh air comes in at some of the crevices, supplying the place of air that leaves by the others, to keep a gas fire burning continuously. If it is cold the fresh air forms a layer on the floor and devotes itself almost exclusively to the combustion of the gas. The local circulation is fairly simple; the stove or hot-water pipes cause an upward current, the window a downward current, and so there exists a fairly active circulation between the stove, or water-pipes, and the windows. The persons in the room also cause upward currents, so that the air is kept fairly well mixed. Here our description of the circulation ceases; the length of time that such a room is endurable depends first upon its size and secondly upon the powers of endurance of the individuals. The gas stove is an aggravation of the defect; the hot-water pipes, especially in a large hall, help to keep the room habitable somewhat longer than if they were not present by promoting the local circulation.

2. Room with Single Opening

34. The unsatisfactory character of the air of the preceding example leads us naturally to the second, which we may represent by a room with an open window. It will materially aid the correct appreciation of this case if we consider the liquid analogue of it. Imagine a glass box filled with oil and

immersed in a large tank of water, and imagine further an opening to be made in the side of the box of oil. The oil being lighter than the surrounding water, the water would flow in at the lower part of the opening and drive the oil out at the upper part of it; after passing into the box the water would settle down to the bottom and form a layer there. The replacement of oil by water would go on until the part of the box below the level of the top of the opening was filled with water; then the circulation would cease.

The oil cannot mix with water, so that the analogy is not quite strict. A more accurate representation would be secured by using water in a solution of salt, but in this case, as in the case of hot and cold air, the mixing which takes place between the inflowing air and the surrounding air is not sufficiently extensive to destroy the analogy.

In a room with a single vertical aperture on one side we have, therefore, a 'general circulation,' air entering by the lower part of the aperture and issuing by the upper part. The 'local circulation' depends very largely

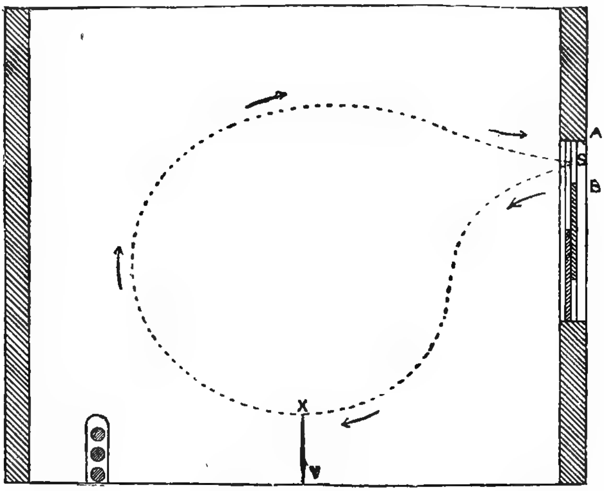


Fig. 31.

upon the position of the water pipes, but if they are at some considerable distance from the positions vertically under the opening, a cold shower of air and a cold current along the floor are inevitable, together with a warm ascending current from the hot pipes, ultimately reaching to the opening. The action of the wind in this case affects the velocity of ingress, and therefore the position at which the cold air shower is most keenly felt. The common outcry in such a case for having the windows opened 'on the other side of the room' is merely evidence of the intensity of the cold shower, which is really unavoidable by any such expedient. If the hot pipes are immediately under the windows the state of affairs may be improved by the mixing of currents; but cold air is very persistent in finding the floor level.

The calculation of the effect of a single opening, as that described, can be arrived at by considering the course of the air from its entry to its exit, and regarding the part in motion as separated from that, comparatively speaking, at rest by imaginary partitions.

We may roughly indicate the boundary of the flow by the dotted line in fig. 31, A B being the orifice, and S the point of division into inlet and outlet. If the line X Y be a line dividing the upcast part from the downcast, X Y may be treated as the section of a chimney flue for which S B is the inlet orifice, and A S the outlet orifice; the head will be due to the difference of density of

the air in the portion S B to X Y, and the portion X Y to A S respectively; if we can assume the air of these two portions to have mean temperature t and T respectively, the head $\mathfrak{h}$ (p. 82) will be roughly $\frac{1}{500}$ (T $-t$) H, where H is the height of the window opening above the floor. The resistance to the flow will arise from the window-opening merely; at other parts of the flow the resistance will be very small. Suppose A to be the area of the opening and that the inflow area and outflow areas are equal, each being equal to $\frac{A}{2}$. Then taking these areas as being thin plate orifices the resistance of each will be $R = \frac{1}{27A^2/4} = \frac{1}{7A^2}$ approximately.

The total resistance will therefore be $\frac{2}{7A^2}$,

and the flow will be

$$\sqrt{\frac{\mathfrak{h}}{R}} = \sqrt{\frac{(T-t)}{500} \cdot \frac{H \times 7A^2}{2}}$$

$$= A\sqrt{\frac{(T-t)\,H}{140}} \text{ cubic feet per second,}$$

or $$\sqrt{\frac{(T-t)\,H}{140}} \text{ cubic feet per square foot of opening.}$$

Example.—*The temperature of a room is 70° F., the external temperature 20° F.; a window 14 feet above the floor is opened so as to give an aperture 3 ft. 6 in. wide × 2 ft. high: find the amount of air that will flow in per second.*

We shall here assume the temperature of the upcast to be 70° and that of the downcast 20°. Such a distribution is only a rough approximation to the actual state of things after the window has been opened some time.

By the above calculation the flow is

$$7 \times \sqrt{\frac{50 \times 14}{140}} = 15{\cdot}6 \text{ cubic feet per second.}$$

The velocity at entry will be about five feet per second, and elsewhere it will be inversely proportional to the section of the moving stream.

35. When the aperture is in the ceiling instead of the side the problem is very similar, but there being no top or bottom division of such an aperture, an interesting modification is produced that may also be illustrated by the liquid analogue. A heavy fluid on the top of a light one, as when a bottle of water without a cork is immersed in a larger vessel of salt solution, or, to take a commoner example, when a bottle of water is inverted, and the cork withdrawn, is really in unstable equilibrium; and, as a rule, the fluids of different densities begin to change places. But the character of the motion is different according to the size of the orifice; if this be large the lighter fluid runs up one side, and the heavier down the other; if it is very small indeed no flow takes place at all; for apertures of intermediate size we get the intermittent flow that is a familiar phenomenon observed whenever a bottle of water with a narrow neck is inverted. This interesting case arises because the two fluids cannot divide the channel between them. Similar phenomena are exhibited with air. If a candle is burned in a bell-jar, the only aperture of which is a long narrow tube, the air which comes out in consequence of the expansion by heat prevents the outside air from entering, although it is heavier than the internal air beneath it, and the candle ultimately becomes extinguished for want of oxygen. If, however, the aperture is sufficiently wide a circulation results, and between these

limits we have the intermittent draught and back draught that a wide chimney exhibits when there is not a sufficient supply of air inlets in the room. If, however, the aperture be divided into two parallel parts by a vertical partition, when once the cold air has gone down one side and the warm air up the other the flow is stable and continuous.[1]

The local circulation for a double aperture in the ceiling acting as inlet and outlet is not sufficiently dissimilar from that of an aperture in the side for us to devote more space to it.

The effect of such an arrangement can be calculated in a manner very similar to the case of the aperture in the side. Taking the mean temperature of the whole height H of the downcast (which must be measured from the outside of the ventilator to the floor of the room) as being t, and the mean temperature of the whole upcast as T, we have the head

$$\mathfrak{h} = \frac{1}{500}(\mathrm{T} - t)\,\mathrm{H}.$$

The resistance R would be due solely to the channel through the ceiling, and can be calculated by the rules of § 20; from these two the flow can be determined.

Example.—*A room, the temperature of the air of which is* 70° *F., is provided with a vertical ventilating shaft from the ceiling to the external air. The length of the shaft is* 5 *feet, and it is divided by a partition into two parallel tubes, the area of each of which is* 1 *foot* × 9 *inches; find the flow through the shafts if the external temperature be* 20° *F. The height of the room is* 15 *feet.*

Taking the temperature of the whole downcast at 20° F., and of the whole upcast at 70° F., the height from floor to top of ventilator being 20 feet, we have, as in the previous example, the head

$$\mathfrak{h} = \frac{1}{500} \times 50 \times 20 = 2 \text{ feet of air.}$$

In order to calculate the resistance, we may consider each comparatively short wide tube as a cylindrical mouthpiece, which has a coefficient of contraction ·8. The resistance of each will therefore be (§ 20 (*a*) and (*h*)):

$$\mathrm{R} = \frac{1}{64{\cdot}4}\left\{\left(\frac{1}{{\cdot}8^2} - 1\right) + 1\right\}\frac{1}{\left(\frac{3}{4}\right)^2}$$

$$= \frac{1}{64{\cdot}4} \times \frac{16}{{\cdot}64 \times 9} = {\cdot}0431.$$

The resistance of the whole circulation will therefore be ·086; from which we get the flow $= \sqrt{\frac{2}{{\cdot}086}}$, or about 5 cubic feet per second. The velocity of influx is about 6 feet per second.

3. Room with two Separate Openings

36. The next stage in the development of a complete ventilation system is a room with two separate openings, one of which acts as an exit flue and the other as an inlet. This is the typical case referred to above (p. 62), and we need not consider further the general theory of the circulation. It is,

[1] This principle is exemplified in Watson's ventilator and Muir's ventilator.

however, a case of such very frequent occurrence, every room with an open fire and no special inlet being substantially an example of it, that we are led by its importance to consider some of the details. Let us consider first of all the case of a room with an open fireplace, and an inlet whose equivalent orifice is i; let the equivalent orifice of the chimney be o; then if $\mathfrak{h}$ be the head in feet of air, we have the flow

$$V = \sqrt{\frac{\mathfrak{h}}{\frac{1}{27i^2}+\frac{1}{27o^2}}} = \sqrt{\frac{27\mathfrak{h}}{\frac{1}{i^2}+\frac{1}{o^2}}} \text{ cubic feet per second.}$$

Let us first examine the effect upon the flow of a change of size of the inlet orifice. It is evident that the maximum value of the flow which is attained when i is extremely large, as, for instance, when the room windows are wide open, is $\sqrt{27\,\mathfrak{h}\,o^2}$, and if the inlet be narrowed the flow will be gradually decreased until it ceases altogether, when there is no inlet orifice, i.e. when i is zero. Now we have already seen that a single flue may act as inlet and outlet simultaneously, the cold air coming down one side and the hot going up the other. Hence as the inlet orifice is gradually narrowed we approach this condition. If the inlet orifice be not actually zero, but only very small, there may still be a tendency for this double action of the flue to establish itself, in which case the chimney will 'smoke,' a phenomenon sometimes experienced with chimneys with straight flues, when the access of air to the room is not sufficient. Let us extend the reasoning further, and inquire into the conditions under which this kind of 'smoking' is likely to take place. We suppose a small inlet, say the crevices of doors and windows, with an equivalent orifice i; then there are two alternatives which the air may choose in order to replace the lighter warm air by the heavier cold air: (1) the chimney behaves as an outlet only, the whole air supply coming through the crevices; the flow in this case is

$$\sqrt{\frac{27\,\mathfrak{h}}{\frac{1}{i^2}+\frac{1}{o^2}}};$$

(2) the chimney acts as both inlet and outlet, air coming also through the chinks. In the second case, if we suppose half the shaft to be occupied with cold air coming down and the other half with warm air, the air coming down the shaft may be regarded as traversing a tube of half the area of the chimney: the equivalent orifice of entry for this duct will be $o/2$, and, by law 4 (p. 64), the whole orifice of inflow will be $i+\frac{o}{2}$, and the inlet resistance

$$\frac{1}{27\left(i+\frac{o}{2}\right)^2};$$

the outlet resistance, that of the other half of the shaft,

$$\frac{1}{27\left(\frac{o}{2}\right)^2};$$

the total resistance will therefore be

$$\frac{1}{27\left(i+\frac{o}{2}\right)^2}+\frac{1}{27\left(\frac{o}{2}\right)^2}.$$

The head may be assumed to be the same in both cases, and hence the flow on the second alternative will be

$$\sqrt{\frac{27\,\mathfrak{h}}{\frac{1}{\left(i+\frac{o}{2}\right)^2}+\frac{1}{\left(\frac{o}{2}\right)^2}}}.$$

Now we have to decide which of these two alternatives the air will choose. We may assume that that alternative will be chosen which offers the least resistance, and this will be the second one if

$$\frac{1}{\left(i+\frac{o}{2}\right)^2}+\frac{1}{\left(\frac{o}{2}\right)^2} \text{ is less than } \frac{1}{i^2}+\frac{1}{o^2}.$$

It can be shown that the condition is that i should be less than $o/2$. Hence we find that the chimney will 'smoke' if the total area of the inlet orifice is less than half the equivalent orifice of the chimney. This result is of considerable interest, but it cannot be pressed with great numerical accuracy on account of the numerous assumptions made in the course of the reasoning; but it is sufficient to show in a striking manner the importance of providing sufficient inlet area. Further, it may explain a well-known empirical principle advocated by some architects, namely, that to prevent smoking, a chimney should not be straight but bent. It is easy to see that at the bends the up and down currents would mix, and the division of the shaft between the two could hardly under any circumstances be established, and, therefore, this particular cause of smoking could not be active in a chimney with a bent shaft.

In the equations we have used hitherto we have neglected the change in the density of air when it is heated; we have, in fact, assumed the flow in cubic feet per second to be the same at the inlet and the outlet. If, however, the difference of density is too great to be neglected, we may correct the equations as follows. Dividing the total head into partial heads h_1 and h_2, we have for the flow V′ through the outlet in cubic feet per second

$$V'^2 = \frac{h_1}{\frac{1}{27o^2}}$$

and for the flow through the inlet, $V^2 = \dfrac{h_2}{\frac{1}{27\,i^2}}$.

$$\therefore\ \mathfrak{h}=h_1+h_2=\frac{1}{27i^2}V^2+\frac{1}{27o^2}V'^2.$$

But if Δ is the density of the cold air, and Δ' that of the warm air, $V^2\Delta^2 = V'^2\Delta'^2$.

$$\therefore\ \mathfrak{h}= V^2\left\{\frac{1}{27i^2}+\frac{1}{27o^2}\cdot\frac{\Delta^2}{\Delta'^2}\right\}$$

$$=V^2\left\{\frac{1}{27i^2}+\frac{1}{27o^2}\frac{\{1+\alpha(T-32)\}^2}{\{1+\alpha(t-32)^2\}}\right\},$$

where T is the temperature of the air in the shaft, t the external temperature, and α the coefficient of expansion of air, i.e. 1/491.

Hence $$\mathfrak{h}=\frac{V^2}{27}\left\{\frac{1}{i^2}+\frac{\{1+\alpha(T-32)\}^2}{o^2\{1+\alpha(t-32)\}^2}\right\},$$

and $$\mathfrak{h} = \frac{1}{459 + t} (T - t) H \quad . \quad . \quad . \quad (\S\ 28.)$$

This somewhat complicated calculation can easily be pursued, by those who have some acquantaince with mathematical methods, to show that the flow does not increase indefinitely with the temperature T of the air in the flue. It reaches a maximum at a temperature which is given by the equation

$$T - t = (459 + t)\sqrt{1 + \frac{o^2}{i^2}}.$$

So that if the inlet orifice is very great compared with the outlet, the maximum is reached at a temperature $523 + 2\ (t - 32)$; otherwise the temperature of maximum flow will be much higher; indeed, practically, the inlet orifice is very small, the flow increases with the temperature up to the limits of temperature ordinarily attainable.

37. Two special points about the construction of chimneys require our attention. First it is usual, in register grates especially, to make the communication between the fire-place and the chimney somewhat smaller in area than the chimney shaft; this narrowed area is called the throat of the chimney. It affects the resistance by requiring the velocity of the air to be increased in order to get the same flow through the narrower passage, and is therefore an artificial contraction of the orifice, and its effect may be represented by a suitable coefficient of contraction. If, as is generally the case, the sides of the throat are coved, then, roughly speaking, no coefficient of hydrodynamical contraction will be required for the throat itself, regarded as an aperture, so that the effect of the throat becomes the same as if it were an orifice with a coefficient of contraction equal to the ratio of the measured area of the throat to the measured area of the shaft. Let ϕ be this ratio, then the resistance due to the throat is

$$\frac{1}{64{\cdot}4}\left(\frac{1}{\phi^2} - 1\right)\frac{1}{A^2},$$

where A is the area of the shaft.

Secondly, it is usual to provide the orifice of a chimney flue with a chimney-pot. The result is, generally speaking, a narrowing of the orifice of discharge, and this is, from the scientific point of view, the object of the addition. While the area of the shaft of the chimney should be decided from the consideration of the greatest possible flow of air, and should therefore be of considerable size, the area of the orifice of discharge is determined with a view of securing a sufficient velocity of discharge to give adequate stability to the draught. General Morin assigns 5 feet per second as the proper velocity in the chimney and 10 feet per second as the most suitable velocity of discharge. The best form of chimney-pot is one in the form of a truncated cone with in-curving sides, for in that case the orifice has no coefficient of hydrodynamical contraction *per se*. The effect of such a chimney-pot is to produce an artificial contraction from the area of the shaft to the area of the orifice, and the effect is the same as if a mouthpiece were adjusted which had coefficient of contraction $\frac{a}{A}$, where a is the area of the orifice and A that of the shaft; the resistance added by such an addition to the shaft is therefore

$$\frac{1}{64{\cdot}4}\left(\frac{1}{\left(\frac{a}{A}\right)^2} - 1\right)\frac{1}{A^2}, \text{ or } \frac{1}{64{\cdot}4}\left(\frac{1}{a^2} - \frac{1}{A^2}\right)$$

Adopting General Morin's figures for the velocities, a would be one-half of A and the resistance of a chimney-pot would be $\frac{3}{64 \cdot 4} \times \frac{1}{A^2}$, where A is the area of the shaft.

EXAMPLE.—*Find the flow of air through a room with an open fire, and find the amount of coal that must be burned to maintain it, having given the following particulars. Outlet :—A chimney of circular section* 9 *inches in diameter with two bends of* 45° *each, the first at a height of* 10 *feet from the floor, the second at a height of* 17 *feet, the remaining vertical portion of the flue being* 25 *feet. The chimney is provided with a trumpet-shaped cap with the orifice* 6 *inches in diameter. The throat of the chimney is a semicircular area,* 9 *inches in diameter,* 2 *feet from the ground. Inlet :—A Tobin tube* 6 × 9 *inches, the inside vertical length being* 5 *feet, and the lower part horizontal and* 2 *feet long, covered by a grating of which half the area is occupied by the bars. Temperature of air in the flue* 182° *F. Temperature of external air* 32° *F.*

Head.—If we neglect the small loss of head due to the fact of the cold air having to be forced up the 5 feet of Tobin tube (which will depend on the difference of temperature of the external air and the air of the room) the head h will be $= \frac{150}{491} \times 40$ feet of air, since the total vertical height above the throat is 40 feet.

The *resistance of the outlet* will be made up as follows :—

Resistance due to the throat (assuming that the sides leading to it are coved so as to give a coefficient of contraction equal to unity),

$$\frac{1}{64 \cdot 4} \times \left(\frac{1}{\left\{ \frac{\pi}{2} \left(\frac{4 \cdot 5}{12} \right)^2 \right\}^2} - \frac{1}{\left\{ \pi \left(\frac{4 \cdot 5}{12} \right)^2 \right\}^2} \right) = \cdot 239.$$

Resistance due to friction (hydraulic mean radius ·19 foot),

$$\frac{\cdot 01 \times 43}{\cdot 19 \times 32 \cdot 2} \cdot \frac{1}{\left\{ \pi \left(\frac{4 \cdot 5}{12} \right)^2 \right\}^2} = \cdot 360.$$

Resistance due to bends,

$$2 \times \frac{1}{64 \cdot 4} \times \frac{1}{2 \left\{ \pi \left(\frac{4 \cdot 5}{12} \right)^2 \right\}^2} = \cdot 080.$$

Resistance due to cap,

$$\frac{1}{64 \cdot 4} \left(\frac{1}{\left\{ \pi \left(\frac{1}{4} \right)^2 \right\}^2} - \frac{1}{\left\{ \pi \left(\frac{4 \cdot 5}{12} \right)^2 \right\}^2} \right) = \cdot 323.$$

Coefficient of head spent in producing velocity,

$$\frac{1}{64 \cdot 4} \times \frac{1}{\left\{ \pi \left(\frac{1}{4} \right)^2 \right\}^2} = \cdot 403.$$

Total resistance of outlet, $R_1 = 1 \cdot 405$.

Resistance of inlet :—

Resistance of grating (coefficient of contraction ·65),

$$\frac{1}{64 \cdot 4} \times \left\{ \frac{1}{\left(\cdot 65 \times \frac{1}{4} \times \frac{3}{4} \right)^2} - \frac{1}{\left(\frac{1}{2} \times \frac{3}{4} \right)^2} \right\} = \cdot 070.$$

Resistance due to friction (hydraulic mean radius 0·15 ft.),

$$\frac{\cdot 01\times 7}{\cdot 15\times 32\cdot 2}\times\frac{1}{\left(\frac{1}{2}\times\frac{3}{4}\right)^2}=\cdot 103.$$

Resistance due to one rectangular bend,

$$\frac{1}{64\cdot 4}\times\frac{1}{\left(\frac{1}{2}\times\frac{3}{4}\right)^2}=\cdot 110.$$

Total resistance of inlet, $R_2=\cdot 283$.

$$\text{Flow}=\sqrt{\frac{\mathfrak{h}}{R_1+R_2}}=2\cdot 69 \text{ cubic feet per second.}$$

The amount of coal required to be burned for this circulation can be determined from the flow, with the knowledge of the amount of heat developed by the combustion of 1 lb. of coal (p. 122), the density and specific heat of air, and the given rise of temperature.

38. It remains for us to consider the local circulation in such a room as here discussed. If the inlets all supply cold air the distribution of the air on entering may be inferred from fig. 29 (p. 90). It results in the formation of a layer of cold air on the floor, moving with appreciable velocity towards the fireplace and causing a cold draught to the feet. This will be the case in a large room, even if the air is directed into the room, by Tobin tubes or otherwise, with a vertical motion; in a small room the greater part may be occupied by the descending shower indicated in fig. 29, and the cold layer may not have space to form. This effect might be modified to a certain extent by having a large number of narrow Tobin tubes made of metal, instead of a single one made of wood, as the air would in the former case issue from the tubes more nearly at the temperature of the room, whereas with a good thick wooden case the air is kept as nearly as may be at the external temperature until it is actually in the room.

There will be rapids at each inlet orifice and in the immediate neighbourhood of the grate, but their effect is not very conspicuous unless the air is very cold.

The general type of local circulation for a room with an open fire and cold air inlets will therefore be rapids at entry and exit and a cold layer from one to two feet thick on the floor moving towards the fire. It is, however, interfered with by local causes, the most important of which are the surfaces considerably heated by direct radiation from the fire.[1] In particular, the floor immediately in front of the fire gets warmed in this way and helps to warm the air passing over it, and if the radiation is sufficiently intense and the flow restricted, a column of ascending air is formed in front of the grate and the fire is fed by the cold air from the sides coming round the rising column. A fender which screens the hearth-rug from the direct radiation of the fire keeps the rising column within its own area, where it may often be easily detected.

If the entering air is warmed to a temperature the same as that of the room it will mix more completely with the air of the room, and the formation of a current along the floor will be avoided. If its temperature exceeds that of the air of the room, a layer of warm air will be formed at the ceiling, and will of course ultimately fill the room unless it escapes by ventilators in the ceiling. It becomes mixed with the respired air rising from the occupants of the room, so that adequate ventilation with warmed air requires the full supply specified in section 52).

39. An interesting case of local circulation occurs when a room with an open

[1] See the distribution of the temperature in the figure, p. 110.

fire and cold air inlets, or no special inlets, is also lighted by a number of gas jets on the same level. As shown later, p. 115, the intense heat of the burning gas causes a local circulation which does not practically extend below the plane of the burners; we then get the room divided into three almost independent zones, a torrid zone from the ceiling to somewhat above the level of the gas jets, mainly occupied by very foul air, especially in the upper part; a frigid zone extending from the floor to about one foot in height occupied by the fresh entering air on its way to the fire: between these two is a temperate zone of air without any special circulation. Diffusion and special local causes produce a certain amount of intermingling of the air of these three zones, and in particular the boundary between the torrid and the temperate zones is very ill-defined, the temperature rising gradually towards the

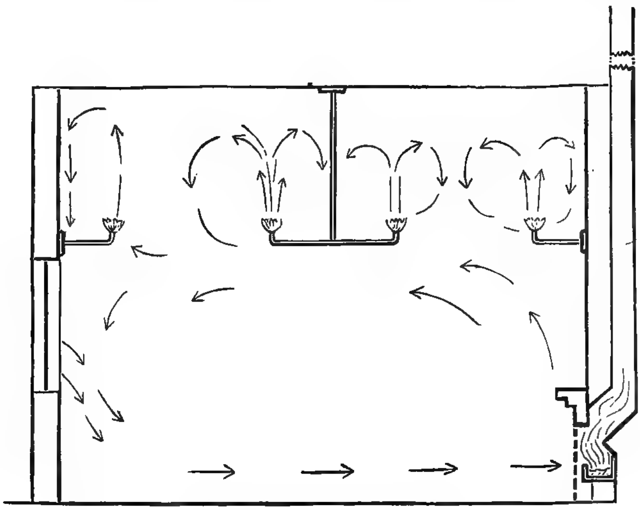


FIG. 32.

ceiling where it is very high; but the separation is fairly complete, and thus the effect of burning a number of gas jets as described is practically to reduce the height of the ceiling of the room. The state of the air in the temperate zone is not generally regarded as unendurable, but the occupants would be much better supplied if they could breathe at a lower level than is usually the practice. An ideal diagram of the stream lines of the local circulation in this case is given in fig. 32.

A diagram showing a special instance of local circulation in a room with an open fire is given later, p. 110.

4. Room with one Outlet and several Inlets

40. We have already indicated the treatment of this case. If the inlets are direct from the open air, or cold air inlets, they are equivalent to a single inlet with an equivalent orifice equal to the sum of the equivalent orifices of the separate inlets. If they are hot air inlets, there may be some appreciable head due to the inlet itself which must be allowed for. Thus if the outlet head would produce a partial head h_2 for one inlet duct, and the duct itself, reckoned separately, produces a head H' the actual effective head for that duct would be h_2+H', and the flow must be calculated accordingly.

5. Room with two Outlets and one Inlet

41. This is a case of very frequent occurrence, being realised whenever a separate ventilator is provided with special flue to take away heated air in a

room which has an open fire. One of the most frequent phenomena exhibited is that the ventilating shaft acts as an inlet and lets in cold air instead of removing warm air. The reason for this back draught we shall endeavour to explain.

Suppose $\mathfrak{H}$ the total head due to the chimney; it may be divided into two partial heads, h_1 for the chimney regarded as a duct, and h_2 for the flow through the inlet. Let R_1 be the resistance of the chimney, R_2 that of the inlet duct. Let H' be the separate head for the ventilating flue, depending on the difference between the temperature of the air in it (and in the room) and that of the outside air; then the effective head for that shaft is $H'-h_2$, since the flow for the two heads separately would be in opposite directions. Thence if $H'=h_2$, the head becomes zero, and the flow through the ventilator ceases, and at that instant the ventilator does not affect the circulation through the room which would be produced by the chimney alone. We can therefore calculate h_2 as though the ventilator were closed. But since $h_2 = R_2 V^2$, and $h_1 = R_1 V^2$, and $\mathfrak{H} = h_1 + h_2$,

we have
$$\frac{h_2}{\mathfrak{H}} = \frac{R_2}{R_1 + R_2}.$$

And the condition for cessation of flow is, therefore,

$$\frac{H'}{\mathfrak{H}} = \frac{R_2}{R_1 + R_2}, \text{ or } \frac{H'}{\mathfrak{H}-H'} = \frac{R_2}{R_1}.$$

Now the head $H' = \frac{1}{459+t}(T'-t)\,H'$, where T' is the temperature of the air in the ventilating flue and H' its height from the room floor to the external orifice, and a similar relation holds for the head for the chimney, so we get the following result:—The ventilator ceases to draw air from the room as soon as the inlet orifice is so narrowed that the ratio of the resistance of the inlet to that of the chimney-flue is equal to, or greater than, the ratio of $(T'-t)\,H'$ to $(T-t)\,H-(T'-t)\,H'$. Supposing that the chimney and ventilating flues are of equal height, the ratio becomes $T'-t : T-T'$. That is, for the ventilator to act, the excess of temperature of the air in the flue, above that of the outside air, must bear a greater ratio to the excess of temperature in the chimney over that of the air in the flue than the ratio of the resistance of the inlet to that of the chimney. If a and a' be the equivalent orifices of the chimney and inlet respectively

$$\frac{R_1}{R_2} = \left.\frac{a'}{a}\right|^2$$

whence we get:—the condition for action of the ventilator is a'/a must be greater than $\sqrt{\frac{T-T'}{T'-t}}$.

Thus it appears that with a given chimney the action of the ventilator depends upon the area of the orifice of inlet, and if we take as an instance a chimney whose equivalent orifice is 30 square inches with the temperature of the air in its flue 250° F, and that of the air in the room and ventilating flue 70° F., the outside air being at 50° F. the ventilator will cease to act if the inlet orifice is less than $\sqrt{\frac{250-70}{70-50}} \times 30$ square inches, i.e. 90 square inches.

This area of inlet is seldom realised in practice, and therefore it is not surprising that under ordinary circumstances a ventilator nearly always declines to act as intended.

We have found the condition that the head for ventilation in the flue is

exactly balanced by the partial head produced by the chimney; but such balancing can be only instantaneous, for the equilibrium is unstable. If the cold outside air penetrates a little way down the flue, the head for outward flow is reduced in consequence, and cannot any longer sustain the pull of the partial head, so the cold air flows further down, and the head is thereby still further diminished, and so the ventilator immediately acts as an inlet instead of a balanced outlet, and here an interesting point becomes clear. In order to resuscitate the outflow when the inlet is enlarged to a sufficient size to maintain it, if it were once established, we require a head in the flue; but this cannot arise until the flue is filled with warm air, and this will not naturally occur, as it now acts as an inlet. It may occur fortuitously by the action of a gust of wind across the top of the flue; otherwise it can only be restarted by increasing the inlet to such a size that the partial head produced by the chimney is so reduced that the head due to the warm air in the room is sufficient to overcome the flow down the ventilator and start a fresh flow upward.

6. Room with two Inlets and two Outlets

42. We shall consider only the special case, when the two outlets have equal heads, and we shall investigate the conditions under which the flow through one inlet shall be adequate to supply the one outlet, while the second outlet is fed entirely by the second inlet, so that the complex ventilation system may be divided into two separate simple systems. One of its practical applications is as follows. Suppose two adjoining rooms (fig. 33) with a door between them have each an open fire, and neither of them is pro-

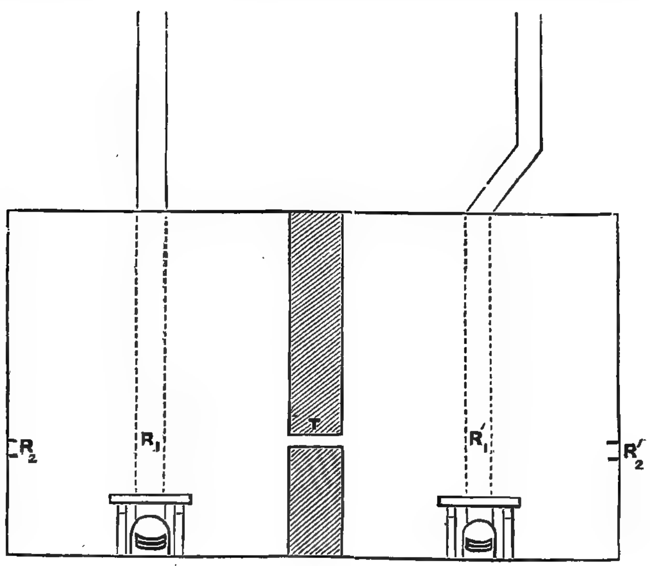


Fig. 33.

vided with any special inlet. Suppose that the height, and the temperature of air in each chimney are the same, will there be any flow of air between the rooms, and if so in which direction?

If the rooms communicate by a large opening like that left by an open door, there may be local circulation between the two. This we are not considering, and therefore we shall suppose that the area of communication is

very small, by means, for instance, of a narrow tube. We may represent the arrangement by fig. 33, in which T represents the tube. If there is no flow through this tube the two systems will be independent, and can be treated as if the tube were actually closed. On this assumption the head $\mathfrak{H}$ for the one circulation may be regarded as divided into two partial heads, h_1 and h_2, for the outflow duct and inflow duct respectively. Let the resistances of these ducts be R_1 and R_2 respectively; then we have

$$h_1 = R_1 V^2,\ h_2 = R_2 V^2;$$
$$\therefore \frac{h_2}{\mathfrak{H}} = \frac{R_2}{R_1 + R_2}.$$

If $\mathfrak{H}'$, h_2', R_1', R_2' be corresponding quantities for the second circulation, we have in precisely the same way,

$$\frac{h_2'}{\mathfrak{H}'} = \frac{R_2'}{R_1' + R_2'}.$$

Now h_2 is the head for inflow or difference of pressure between the one room and the outside air, and h_2' is the difference of pressure between the other room and the outside air; hence if these two are equal the pressure will be the same throughout the two rooms, and no cross flow will take place. The condition of no cross flow is therefore $h_2 = h_2'$, and if h_2 be greater than h_2' the flow will be in the direction from the second room to the first. Since we supposed the temperature in the two chimneys to be the same we have $\mathfrak{H} = \mathfrak{H}'$. Hence the condition is

$$\frac{R_2}{R_1 + R_2} = \frac{R_2'}{R_1' + R_2'},$$

or

$$\frac{R_1}{R_2} = \frac{R_1'}{R_2'}.$$

In words:—There will be no flow between the rooms, or the two circulations will be independent, if the ratios of the resistance of inlet and outlet be the same for the two circulations; and if the ratio of inlet to outlet be greater for the one circulation than the other, there will be a flow from the circulation with the greater ratio to that with the less ratio.

This condition has been tested experimentally on a small scale and found to apply with very great accuracy.[1]

We have assumed the head for each of the two circulations to be the same; it is evident that a condition can be obtained in like manner if that is not the case; but it leads to somewhat more complicated expressions. The reasoning shows very clearly the precautions that must be taken to isolate any circulation without actually completely separating the rooms, or at any rate to secure that, if two circulations interfere, the air shall pass between the two in a given direction. Take, for instance, the following case. One room of a house is occupied by an infectious fever patient, and it is desirable to adopt precautions to prevent the air of the patient's room passing into the house. The provisions to be aimed at are first, an outlet duct with a head for ventilation in the room itself; an open fireplace and chimney will, of course, suffice, and the higher the temperature of the air in the chimney the better; secondly, the ratio of the equivalent orifice of inlet to that of the chimney must be at any rate not greater than the corresponding ratio for the adjoining spaces; in the absence of special measurements make the inlet openings in the infected space *small*, and the inlet openings for the rest of the house as *large* as possible.

[1] Shaw, *Proc. Roy. Soc.* March 1890.

EXPERIMENTAL INVESTIGATION OF THE ACTION OF A VENTILATION SYSTEM. INSTRUMENTS FOR DETECTING AND MEASURING CURRENTS OF AIR

43. In considering the practical applications of the principles which have been laid down in the preceding pages it will be at once evident that successful ventilation must satisfy two fundamental conditions. For the sake of clearness we will continue to regard the ventilation system as represented by a single chamber to be supplied with air, and therefore provided with inlets and outlets. The two fundamental conditions are: (1) That sufficient air should be made to flow through the system; (2) that on passing into the chamber it should be so distributed as to replace foul air and not to cause cold draughts. We wish now to deal with the methods of determining in what way, and to what extent, a particular ventilation system is faulty with respect to these two fundamental conditions. Unsuccessful ventilation is of course generally detected by anyone who has the misfortune to be exposed to it, without any special directions for finding it out. But it is important to be able to decide whether the want of success is due to want of air or misdirection of air, and in the latter case to find out where the air is going to, whether, in fact, the fault lies in the 'general circulation' or in the 'local circulation.' The two conditions which have been laid down may most conveniently be treated separately. We shall first mention the apparatus by which an examination of the system should be made.

Examination of the General Circulation

44. The question whether the air-supply is sufficient is capable of being tolerably accurately answered, provided that the outlets or the inlets can all be identified and measured with sufficient accuracy. It must, of course, be remembered that if special inlets are provided the air will not necessarily pass through them exclusively. A difference of head determines a flow of air through every orifice, great or small, whether intended for the admission of air or not. For the same difference of head, the flow is proportional to the area in a thin plane wall which would be equivalent to the orifice. If an alternative opening is provided which is very ample, the head for a casual orifice, or crevice, may be very much reduced, but it will not be absolutely zero, so that there will always be some flow through the crevice. We shall suppose, however, that the doors and windows are sufficiently well fitted to prevent any considerable flow through the joints if the room be provided with special inlets. In that case we can measure the circulation by measuring the area of each inlet and the mean velocity of the air passing through it. The area of the shaft can be calculated from a scale plan of its section. If the opening is covered by a grating it is better to adapt a continuation of the shaft in zinc or cardboard. The velocity may be measured by an anemometer, or air-meter; the pattern most frequently used is a light wheel with inclined vanes and furnished with counting gear and dials. The instrument is represented in fig. 34, and is made by Casella and other instrument-makers. The instrument records directly the velocity of the air in feet per minute by an observation of the graduations passed over by the needle in the same period, but a correction must be added to each observation representing the minimum velocity which will move the vanes. The correction amounts to about 30 feet per minute, or 6 inches a second;

it is determined by the instrument-maker before the instrument is sent out. It could be verified by carrying the instrument along for a known distance in still atmosphere or by mounting the instrument at the end of a long arm attached to a revolving table, measuring the circumference of the circle so described, and comparing it with the result given by the anemometer after a complete revolution.

In order to determine the mean velocity for the inlet, care must be taken to observe the velocity at a number of different points—some near the edge others near the middle—and take the mean of the measurements, or to keep the anemometer moving slowly across the aperture during an observation.

Having determined the mean velocity and the area, the product gives the circulation in cubic feet per minute. The weight delivered per second can easily be calculated if required. When the delivery for each inlet has been measured the total delivery for the whole circulation is obtained by adding.

If there are no special inlets the determination of the circulation must be obtained from measurements of the flow through the outlets, provided these are sufficiently definite. In order to determine the flow of air up a chimney the front of the fireplace should be covered with a case in which an aperture of known area is cut and fitted with a tube. But it must be remembered that, unless the area of the aperture is very large compared with the equivalent orifice of the chimney, the introduction of the case with aperture will affect the flow by affecting the total resistance.

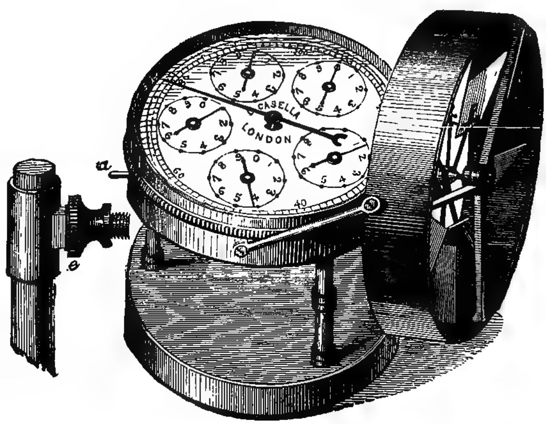


FIG. 34.

Thus, either the amount of air which enters, or, what must be the same, the amount of air which leaves, can be experimentally determined. If both can be measured the determination of the one, of course, checks that of the other. We next require to know the temperature of the air as it enters; any ordinary thermometer may be used for this purpose, but it must be used with discretion, for the reading of the thermometer depends not only on the temperature of the air in which it is placed, but also on the radiation it receives from hot bodies near; moreover, the temperature of the entering air may not be the same at every part of the orifice. The determination of the temperature of the air with the highest accuracy is a very difficult matter, but for the ordinary purposes of an investigation of the ventilation circulation in a system, it is sufficient if the thermometer be simply exposed in the air of the delivery shaft screened from direct radiation, secured from contact with the sides of the shaft, and left until no change of reading occurs during an interval of a few minutes. The thermometer should be of course read *in situ*, and not brought away from the point at which the temperature is required until the reading is taken.

It remains only to consider whether the air is satisfactory as to quality. In order to test this point a determination of the composition of the air must be made, or, at any rate, the amount of impurity must be determined. For information on this point the reader is referred to the article AIR.

The amount of moisture in the air is an important element; it can be determined by any one of the hygrometric methods referred to in the article METEOROLOGY. It is liable to vary considerably in different parts of the circulation.

DIRECT MEASUREMENT OF HEAD OR PRESSURE DIFFERENCES

45. Another element which can sometimes be measured directly is the difference of pressure of air between the two ends of a duct, and from the pressure difference, the head in feet can be easily deduced. The usual instruments for measuring the pressure of air are not, as a rule, sufficiently sensitive for the purposes of ventilation-measurement, as the pressure differences are very minute. In some cases, however, where the head required is large, as, for example, in the ventilation of mines, a syphon water-gauge—a U tube containing water in the bend and having one limb connected by tubes with one end of the ventilation system and the other limb open to the other end—will serve to give the pressure in inches of water by reading the difference of level of the water in the two limbs.

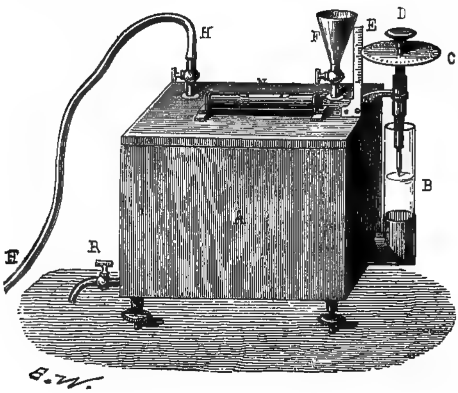


FIG. 35.

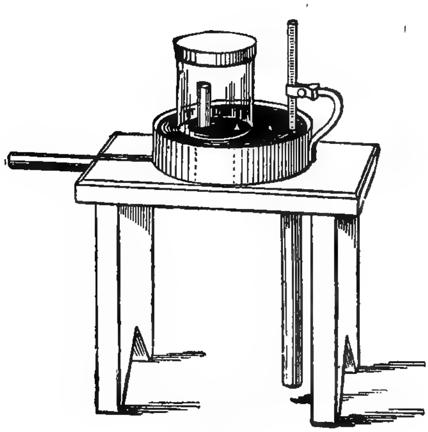


FIG. 36.

An aneroid barometer reading to one-thousandth of an inch can also be obtained, and this may be used for observations in examining the ventilation of a house; but with such an instrument, indicating as it does the pressure of the air where it is placed, a double observation is necessary to get the pressure difference for the two ends of a duct.

There are numerous devices which have been adopted for increasing the accuracy of the reading of the syphon water-gauge. In one modification the one limb of the gauge is expanded into a large square box, while the other is a vertical glass tube in which the rise or fall of the water can be measured by the distance through which a sharp needle-point originally set at the surface of the water, forming the end of a micrometer screw, has to be moved in order that it shall again be at the water-surface. The adjustment of the point can be identified with very great precision, because the image of any object formed by reflection at the water surface is distorted as soon as contact takes place with the point. A figure of such an instrument taken from Peclet's 'Traité de la Chaleur,' vol. i. § 523, is reproduced in fig. 35.

The identification of the position of the surface is still easier if the needle-point be below the surface and brought up to it by the motion of a screw, the most minute elevation of the point above the surface being readily perceived. In this case the reading can still be made by a micrometer screw if the needle is bent into a hook form so that the point turns upwards. A modification which dispenses with the necessity for a screw has been designed by Mr. H. Darwin, of the Cambridge Scientific Instrument Co., and a model constructed and tested by the writer of this article. In this instrument (fig. 36) the needle is fixed to the bottom of a water or oil vessel and the measurement is carried out by observing how much water must be added or removed in order to bring the point of the needle to the surface again after it has been protruded or withdrawn by the alteration of level due to the difference of pressure. The amount of water which would be required for this purpose is determined by finding the extent to which a plunger, a uniform and graduated glass rod, must be pushed down or withdrawn from a small well formed by a vertical tube communicating with the water vessel. From some tests of the instrument made for the Author by Mr. A. Schneider, of Emmanuel College, it appears that the instrument will give readings to within one-three-thousandth of an inch.

Another modification of the syphon gauge which increases the sensitiveness

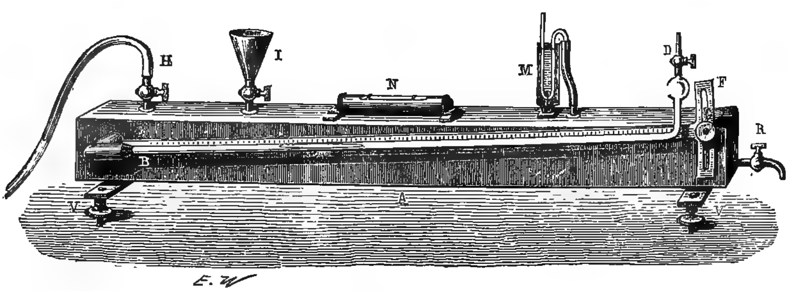


FIG. 37.

consists in using a wide vessel for one limb of the gauge and for the other a long inclined straight tube. As the difference of pressure corresponds to a difference of vertical height of the two water surfaces, the water has to traverse a greater length of inclined tube than of a vertical tube in order to produce the same difference of level; indeed, the length of tube traversed by the liquid in an inclined tube is equal to the vertical difference multiplied by $1/\sin i$, where i is the inclination of the tube to the horizontal. The area of the surface of the water in the other limb must be very great in order that the elevation or depression may practically take effect solely in the inclined tube. A form of this apparatus used by M. Peclet, and described by him in his treatise, vol. i. § 524, is represented in fig. 37.

Many other arrangements for the measurement of small differences of pressure have been designed, some of which are described by Peclet, vol. i. chap. xi.

Examination of the Local Circulation of Air

46. While it is in many cases comparatively easy to determine the total amount of air supplied to a room, the testing of the second condition laid down above as being requisite for successful ventilation is by no means easy. We have no satisfactory means of tracing the course of the air from its

entrance to its exit, and determining its state as to temperature, moisture, and impurity as it flows. The motion of the air is not, strictly speaking, steady in an occupied room, for the velocity and state of the air vary from time to time. The representation, by means of a diagram, of the circulation in a room is almost as difficult as its determination. Any sectional plan can only satisfactorily represent the flow in that section, and the flow in one plane section cannot afford an adequate indication of the whole circulation in the room. It is probable that the difficulties which are referred to above are responsible for the diagrams employed in illustration of the principles of ventilation being frequently, more strictly speaking, finger-posts to show where the air is intended to go than actual tracks of the air. Much interesting information is, however, always to be obtained even from the little that can be learnt of the direction and magnitude of the motion of air in different parts of a room. There are many ways in which information can be got, though none of them are completely satisfactory. The air from different points can be analysed and its temperature can be ascertained, though there are not easy observations in a room of any considerable size and height. Further than that, accurate numerical measurements are not really practicable. A very light wind vane, consisting of a wire with a paper tail, balanced on a needle-point standing in a glass cup, is extremely sensitive to horizontal motion, and indicates by its oscillations whether there is vertical motion too. For observations of vertical motion, a piece of cork, carrying four inclined mica wings, surrounding the end of an inverted thin glass test tube, can be supported by a needle-point and move with so little friction that it will easily show the air current rising from the hand placed several feet under it, and by the rapidity of its rotation indicates satisfactorily, though roughly, the vertical velocity of the air which passes it. By having a sufficiently large number of such vanes and mica-spinners placed at different heights and different positions in a room, a very good idea can be formed of the course of the air currents, which, however, it is very difficult to adequately represent on paper. There are various ways in which the currents may be made more or less visible by loading them with smoke or fumes which are carried along with the current. Smouldering cotton velvet is recommended as being useful in this way; the Commissioners of 1857[1] placed ammonia in a dish in the path of the current and loaded the air passing it with hydrochloric acid vapour. Some other fuming chemical compounds, as stannic chloride, might be used, but all these are liable to change the current to a certain extent, and without exceptional illumination the flow is not visible for a long distance. Balloons, silk fibre, and down are also sometimes employed, and when used discreetly may afford valuable observations; but none of them seem quite so trustworthy as the wind vanes and mica-spinners mentioned above.

The most sensitive method of detecting the motion of air for some purposes is by means of the sense of smell; the path of air through the different rooms of a house can be easily traced by burning a little incense or a pastille (which can be bought at any chemist's) near an inlet. In this case we have, of course, auxiliary information as to the path by which smell comes into a room if at all, viz. through crevices or openings which can, as a rule, be identified. It cannot be used with much effect in a large room, as the path of currents could only be traced by the observer moving about, and this moving would entirely destroy the steadiness of the currents and spoil the observation. The sensation of a cold current, especially as perceived by

[1] *Report of Parliamentary Commission on Warming and Ventilation of Dwellings*, 1857

a moistened finger, may also be used to furnish information as to the direction of flow in any accessible position.

47. It will be gathered from the above that the information which can be obtained as to the local circulation of air through a room is not at all complete, and is difficult of representation; but with one or other of the apparatus mentioned, and by taking advantage of casual indications (such as the deposit of dust on walls, which is a good indication of the course of warm air), an observer may make himself tolerably well acquainted with the course of

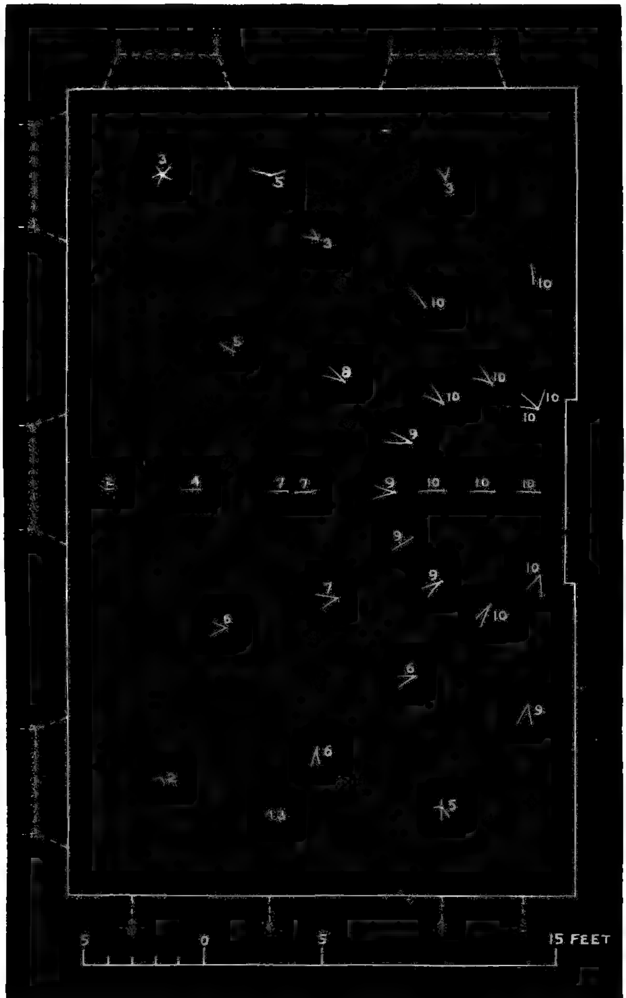
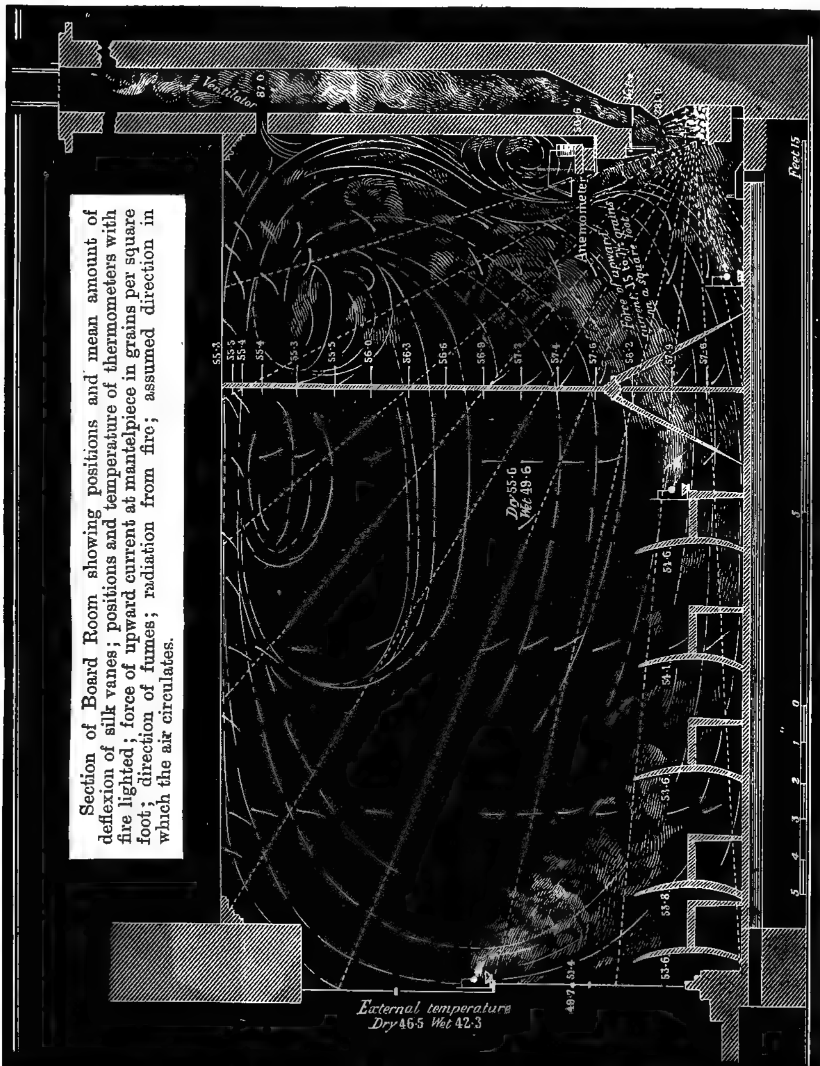


FIG. 38.

currents through the room. We reproduce diagrams (figs. 38–41 and Plate I.), representing the results of experiments of this kind, which will serve to indicate the general features that may be expected in any case. The first two diagrams refer to the circulation of air and the distribution of temperature in a room with an open fire, which were very fully investigated by the Commissioners on Warming and Ventilation of Dwellings, 1857. The diagrams are taken from their report. The first (fig. 38) shows the direction of flow along the ceiling by the direction of deflexion of silk fibres attached to the ceiling, while the amount of the deflexion is indicated by numbers written against the lines

representing the fibres as seen in plan; the second (fig. 39) shows the flow in a vertical section through the middle of the room by representing the deflexion of silk fibres and also by some lines of flow; the temperature in various positions is also indicated. Fig. 40 represents the circulation in a lecture-room in Cambridge heated by hot-water pipes under the tiers of seats, and ventilated through open woodwork in the ceiling into a wooden channel,



Section of Board Room showing positions and mean amount of deflexion of silk vanes; positions and temperature of thermometers with fire lighted; force of upward current at mantelpiece in grains per square foot; direction of fumes; radiation from fire; assumed direction in which the air circulates.

FIG. 39.

extending round three sides of the room, and communicating with a chimney at the corner marked F. In this room no special inlets are provided, some air comes in at A from the lobby, and passes over the hot-water pipes; the rest of the fresh air required comes in by the joints in the windows; the doors in this particular instance generally act as outlets in consequence of the suction from other parts of the building.

In the diagram (fig. 40) the full arrows show the flow in the plane of the section, while the dotted arrows indicate currents near the wall. The strong

upward current of warm air at the back of the room is very clearly shown in the room itself by a deposit on the walls and ceiling.

The most obvious conclusion to be drawn from the diagram is that the air which enters from the chamber containing the pipes passes directly to the extract flue (the velocity of exit is at the rate of 300 cubic feet per minute) without affecting the main body of the air in the room, which remains practically unventilated and unwarmed. The circulation is very much restricted for want of sufficient inlets. There are trap-doors in the ceiling at C above the table, communicating with an airy lumber-room, and the opening of one of these determines a shower of cold air falling directly upon the table. The doors of the lecture-room then become energetic outlets.

The next diagram (fig. 41) shows the circulation on a stone well-staircase in the same building; the doorways represented communicate with corridors and rooms having large window area. There is a coil of pipes on the ground floor. The diagram shows a hot ascending current of air passing

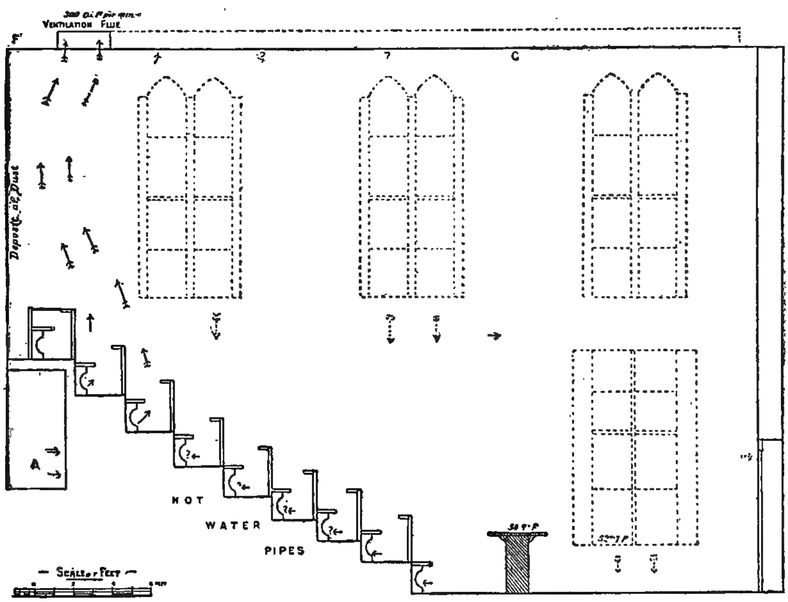


FIG. 40.

up the well of the staircase, and a sort of river of cold air flowing down the steps and turning the corners, part of it finally passing down into the basement. This is really part of a general circulation of air between the hot-water coils and the windows of the whole building, and the circulation can be easily traced, the hot air passing at the tops of the doorways, the cold air at the bottoms. In this case also no special inlets are provided, so that the circulation is mainly internal.

The circulation on a staircase of any house is generally instructive, and a cold descending current from the chimneys and windows of the cold upper rooms can frequently be shown to be active simultaneously with a hot ascending current, generally from the kitchen, and the two currents escape mutual destruction, either by one going spirally round the other, as on the staircase, fig. 41, or by the hot one passing over the cold one. It is this complication of currents that accounts for the thorough diffusion of smells in a house. I have found when experimenting with pastilles upon the

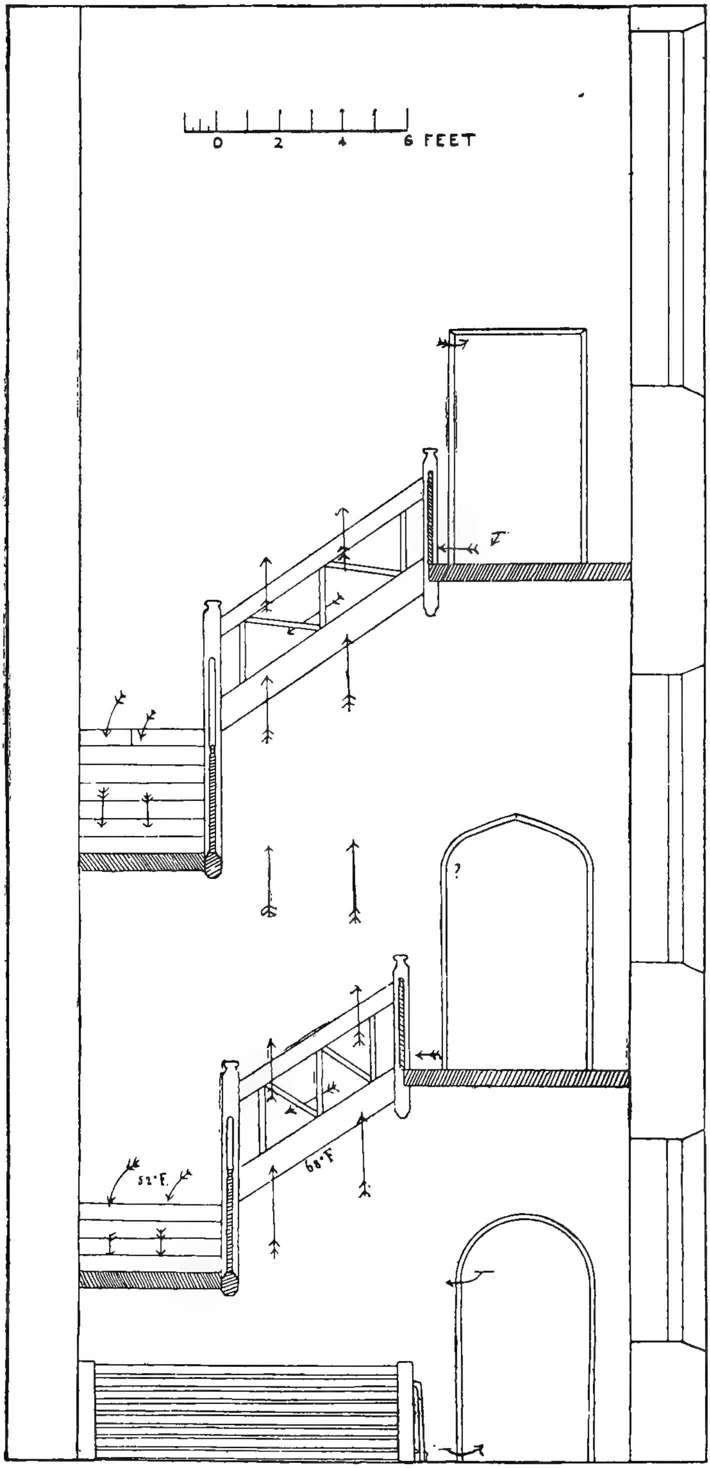


FIG. 41.

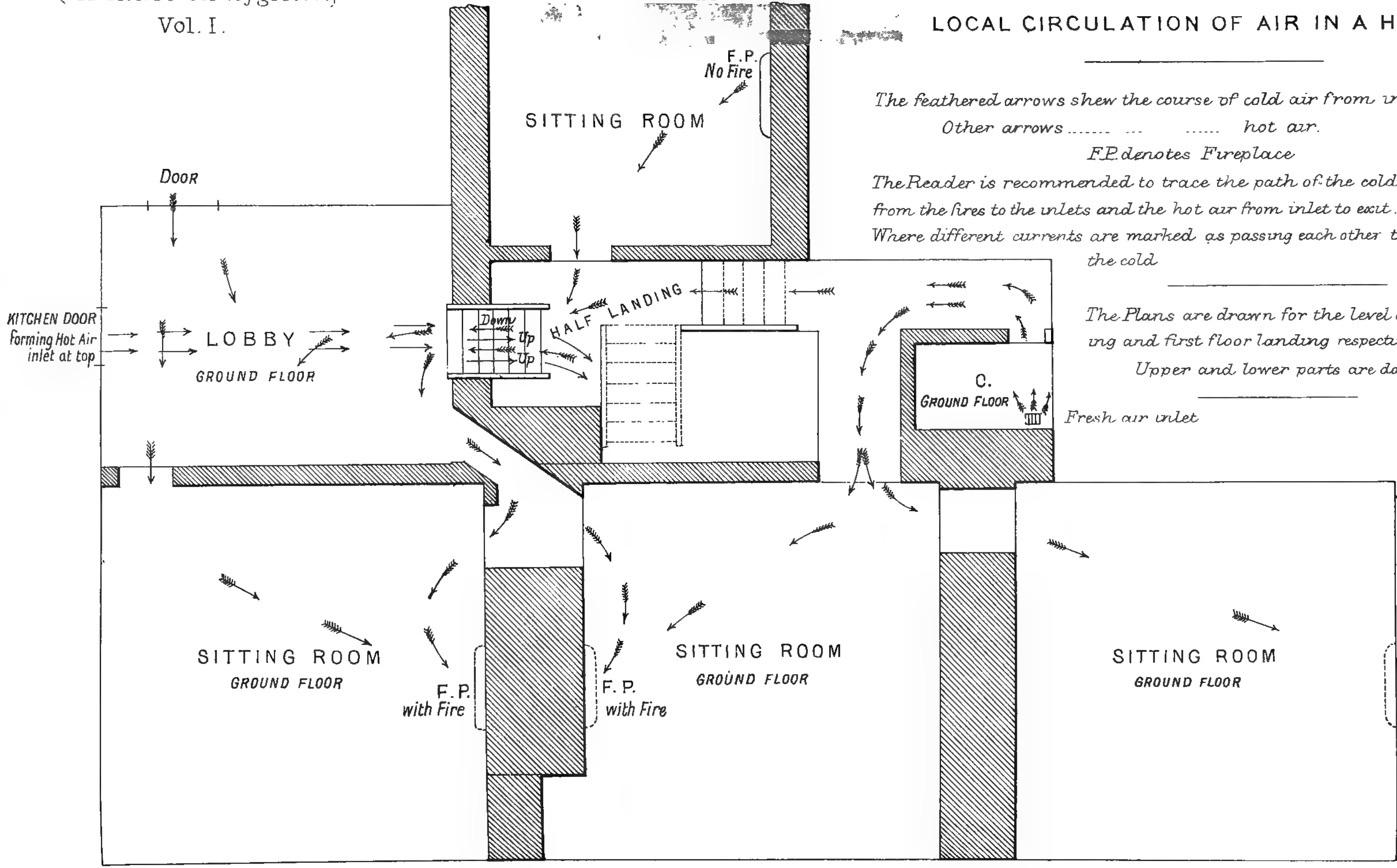
Pl. I.

LOCAL CIRCULATION OF AIR IN A HOUSE.

The feathered arrows shew the course of cold air from inlets to outlets.
Other arrows .... hot air.
F.P. denotes Fireplace

The Reader is recommended to trace the path of the cold air backwards from the fires to the inlets and the hot air from inlet to exit.
Where different currents are marked as passing each other the hot is above the cold

The Plans are drawn for the level of the half landing and first floor landing respectively.
Upper and lower parts are dotted.



West, Newman lith.

circulation in a house (Plate I.) that when a pastille was being burned on the upper floor a layer of air twelve inches thick, flowing downstairs, was charged with the smell, whereas at the height of five feet the smell of cooking was going upstairs. I have attempted to represent the distribution of currents on this staircase by a diagram (Plate I.), where a full arrow denotes rising warm air and a dotted arrow descending cold air. The only means of protecting one's self against such inconveniences, if they be regarded as such, is to provide a competent inlet for every outlet head, and to provide an efficient outlet head for every room where air is likely to be fouled, or charged with disagreeable odours.

48. The examples represented in these diagrams, with those given in figs. 28, 29, and 30, § 31, are sufficient to indicate the two main difficulties of ventilation which arise from the magnitude of the space to be ventilated. They may be called respectively *internal circulation*, the production of currents on account of local differences of temperature by which warm air is carried away from where it is wanted and replaced by cold air causing draughts; and *selective circulation*—the name we propose to apply to the passage of air from an inlet more or less directly to an outlet without replacing as fully as possible the foul air of the room it is designed to ventilate. The objects, then, of an investigation into the ventilation of any room may be conveniently referred to under the headings: sufficiency of supply, internal circulation, and selective circulation.

The defects which may be included under the second and third headings are especially liable to be serious in large rooms, particularly when there are local sources of heat and cold. In theatres they are often disagreeably prominent, and the elaborate arrangements of M. Morin and others are designed to obviate them.

Effect of Adjoining Rooms

49. It will be well here to call special attention to a matter which has been frequently alluded to, namely, that the process of ventilation is a circulation of air through a channel which must have two ends, each end being in the open air. The investigation of the ventilation of any system is therefore not complete until the two sections of communication of the circulation with the open air have been identified.

In investigating the circulation of any room, starting from the outlet and going backwards to the inlet, we must retrace the course of the air until we arrive at the ultimate inlet. This will often be found in adjoining rooms or in closets communicating directly or indirectly with the room in question. In respect of sanitary matters this is a very important consideration, and constitutes a valid objection to the general principle of ventilation by suction. Let us consider, for example, the circulation in a house in winter, in which a number of rooms have fires, each of which causes a head, drawing air, we will suppose, from the central hall or lobby (see Plate I.). Then there will be, in consequence, a head between the central lobby and the external air which will determine a flow of air through every orifice, great and small, in proportion to its equivalent area, unless there is a countervailing head. It follows that all closets, cupboards, rooms, &c., which have an opening to the external air, unless provided with separate flues in which a head is maintained, will contribute to the supply of air to the central lobby from which the rooms, at any rate partially, draw their air. It is needless to say that the air may be rendered quite impure and unfit for use on its way to the lobby and the room that receives it. Experiments can easily be made on this point by loading the air in the places where there are inlets with incense

or some strongly smelling vapour, as that of oil of peppermint, or even tobacco-smoke. I have given one instance, and there are probably many in which experiments of this kind have shown that the supply of air for the fires of most of the living rooms was mainly drawn from the w.c., which had been provided with two openings to secure its ample ventilation. In the absence of special inlets both these openings were acting as inlets for the house, and the current of cold air could be easily traced under the door of the closet and along the floors of the lobby, under the doors of the living rooms to the fires; when it got near the fireplace it was warmed and rose, and so the odour gradually permeated the whole room.

The effect of adjoining rooms with apparatus for separate heads for circulation is frequently very conspicuous. In one instance that has come under my notice a lobby is heated by a ventilating gas-stove with one flue for the supply of fresh air and another for carrying away the products of combustion. In the adjoining room is an open fire. If the gas-stove is lighted when the fire is burning, although the door between the two be shut, no upward current is established in the outlet of the stove; it continues to act as an inlet for the next room; the products of combustion come straight out into the lobby and gradually pass into the adjoining room, where they are readily perceived, and this continues for an indefinite period unless free communication be made between the lobby and the external air by opening the door, when the products of combustion pass up the flue, and there establish a head sufficient to overcome the suction of the next room, and thereafter the desired circulation persists though the outer door be shut.[1]

Artificial Lighting and its Effect on Ventilation

50. We have already noticed that every local source of heat produces convection currents in its neighbourhood. Of such local sources artificial lights are the most effective. The disturbance which they produce in the air depends of course upon the amount of heat which the glowing substance communicates to the air surrounding it, and consequently an incandescent electric lamp is distinguished among all artificial lights by the smallness of the interference with the ordinary course of the air which is caused when the light is used. It is further distinguished by the fact that being inclosed in a glass envelope the glowing filament produces no effect upon the air except the small amount of heating; it requires no oxygen for the maintenance of the light, and therefore does not use up the air of the room, whereas other artificial lights use the oxygen of the air and produce carbon dioxide gas. The following table shows the comparative effect of different sources of artificial light in respect of the heat which they produce, and the heat produced by a human being is likewise included for the sake of comparison:—

Table VII

Source of heat	Heat developed per hour	Cubic feet of carbon dioxide gas per hour
Incandescent lamp (16 candle-power)	200 lb. F. units	0
Average human being	284 „	·6
Candle	291 „	·45
Average gas jet (4 cu. ft. per hour)	2784 „	8

It follows at once that a number of gas jets produce as much heat as a coal fire, and hence when burned in a room may entirely change the course

[1] For the explanation of this effect see above, § 41.

of the currents of air, while at the same time they deliver a large amount of carbon dioxide gas, sulphur dioxide gas, and other impurities, so that, according to Wolpert, for every cubic foot of gas burned 1800 additional cubic feet of fresh air should be introduced. It is therefore clear that a system of ventilation designed for a room in the daytime, when no artificial light is used, ought not to be expected to be successful when a number of gas jets are burning in the room.

If a considerable volume of gas be burned in a room that is unprovided with special exit tubes for the burnt gas, an internal circulation is set up by each gas jet; the circulation does not, however, extend below the level of the burners, so that assuming for a moment that the burners are on the same level the air in the room is divided into two portions by the horizontal plane of the burners (see § 39), and as the combustion proceeds the air of the upper part is rapidly converted into a thick layer of heated foul air, which no human being could endure for any length of time, and the lower section is comparatively uninfluenced. This description is somewhat exaggerated, for the local circulation produced by the fire, if there is one, and by other sources of heat, and the process of diffusion, cause the products of combustion of the gas to be gradually disseminated, but the mixture is by no means complete in ordinary cases. In order to remove the vitiated air the outlets must be placed as near to the ceiling as possible; if they are flues they form suction outlets, which require a corrresponding flow of air to the room.[1] Undoubtedly the most satisfactory arrangement is to provide special outlets to carry away the products of combustion directly from the burners, but that does not alter the effect on the ventilation in respect of the greater total circulation of air required, if other causes, which are used when there is no gas, are still active when the room is lighted; so that the problem of ventilating a room for daylight and gas light is really a double one, and it may not be possible to provide a satisfactory solution of both parts of it by means of a single arrangement.

Summer and Winter Ventilation

51. Somewhat similar remarks apply to the ventilation of buildings in summer. In an ordinary house in winter the chimneys are the warmest parts, and hence, even when no fire is burning, there is always a certain amount of head due to he higher temperature, although the motion of the air may be reversed in consequence of a more powerful head in an adjoining room. But in the daytime in summer the chimneys are frequently the coldest portions of the house, whereas the sun acting on the external walls produces a head causing, with open windows, a circulation downward through the chimneys and through the windows upwards outside the house. This effect is very frequently perceptible by the smell of soot that occurs on very hot days, so that the winter arrangement for ventilation entirely breaks down unless some special device is adopted. The obvious plan in this case is to restore the upward head in the chimneys of those rooms that require ventilation during the day, by gas jets in the chimneys or some other means, or to stop up the chimneys of those rooms and trust to open windows alone for any ventilation that is necessary. The amount of gas that is required to be burned for the purpose of producing a head in a shaft is given on p. 84.

[1] For the condition that such apparatus should act as desired see § 41.

Summary of Conditions to be Satisfied to secure Efficient Ventilation

1. *Quantity of Air Required*

52. The estimates of the quantity of air to be supplied are based upon the following assumptions:—i. That the air of a room must not be permitted to contain more than two volumes of carbon dioxide gas per 10,000 in excess of that contained in the outside air. ii. That the carbon dioxide generated by respiration or combustion is diffused uniformly throughout the room, as likewise is the air which enters, so that the volume to be supplied is that required to dilute the impurity, the average production of CO_2 per head of average population being ·6 cubic foot per hour. On these assumptions the quantity of air to be supplied per hour for a room in *continuous* occupation is 3000 cubic feet per average occupant, or more particularly:

9800 cubic feet per hour for each adult male in hard work.
4750 ,, ,, ,, ,, ,, in light work.
3600 ,, ,, ,, healthy adult male during repose.
3000 ,, ,, ,, ,, ,, female ,,
2000 ,, ,, ,, healthy child during repose.

In hospitals the supply should exceed the above estimate by one-fourth in ordinary cases, and in special cases it should be doubled.

On the same assumptions, in churches, lecture-rooms, and theatres, which are only used for a limited time, and are initially filled with fresh air, respiration can go on for some time before the whole of the air contained reaches the limit of respirable impurity, so that the quantity of air necessary during the first hour is less than that for succeeding hours; the amount depends in this case upon the initial allowance of cubic space per person. For an average audience requiring 3000 cubic feet per hour each, for continuous occupation Dr. de Chaumont calculates the following table of the relation between the quantity of air required in the first hour and the initial cubic space:—

Cubic space in cubic feet per person	Number of cubic feet of air necessary for ventilation during first hour of occupation[1]
100	2900
200	2800
500	2500
1000	2000

Every cubic foot of gas burned per hour requires 1800 cubic feet of fresh air to be supplied if the products of combustion mix with the air of the room. One candle burning requires about 150 cubic feet of air per hour, and an oil lamp requires as much as a gas jet in respect of dilution of the CO_2, but frequently no allowance is made for candles or lamps. The reason for this is not apparent unless it be that the products of combustion of candles and lamps are (under favourable circumstances) without smell or taste; whereas a burning gas jet produces effects which indicate, without special analysis, that the limit of respirable impurity has been exceeded.

[1] When the air is drawn by a very wide chimney, 60 feet high, with the temperature of the air in it 212° F., and the outside air at 32° F., this estimate requires a clear orifice of about 7 square inches per person. This is almost impracticable, and consequently an endeavour should always be made to take advantage of the local circulation to have the occupants in the parts of the room where the air is fresher than elsewhere.

2. *The Quality of Air Required*

53. *Purity.*—It is essential that the air should be drawn from a pure source, and if necessary further purified before admission to the rooms. To secure purity it should be drawn from vertical openings, preferably in a north wall, from some considerable height above the ground, free from local contamination. The openings may be protected by louvres. The most serious impurities of outside air lie in the dust which often contains the germs of disease. This may be partially removed by filtering through canvas or by other means suggested in § 13.

54. *Temperature.*—The temperature of the air which enters a room requires regulation according to special circumstances, and for this purpose the entering air should be warmed, and provision should be made for mixing cold fresh air with the warm before entry into the room in a proportion adjustable by a register-door, or valve.

The temperatures which should be maintained in various buildings are given by Morin [1] as follows:—

Schools	15° C.	59° F.
Hospitals	16°–18°	61°–64°·5
Accident wards	12°	54°
Shops, barracks, prisons	15°	59°
Theatres, assembly-rooms, lecture-rooms	19°–20°	66°–68°

But it must be remembered that no temperature will suit all persons; a room that seems intolerably hot to a person freshly entering after a brisk walk on a cold day may seem inadequately warmed to those who have been engaged in it for some hours in sedentary occupation.

55. In some instances the warming of buildings is carried out entirely by hot air; in such cases the entering air must be at a temperature above the mean temperature to allow for losses of heat through windows and walls. Such a plan does not seem the most desirable. Hot air warming is often said to be dirty. The hot air moving over cold surfaces produces dust deposits, though this may be an advantage, as it is a means—not a very satisfactory one—of getting rid of the dust from the air; but there are advantages in heating the walls and furniture by means of direct radiation and not by hot air contact, for this promotes circulation of air, even in remote corners, and prevents loss of heat from persons by radiation; so that it would seem advisable where such a plan is feasible to allow the air to enter at a temperature of a degree or so below that of the room and make up the necessary supply of heat by open fires or hot-water pipes. There are incidental advantages in this method, as it reduces the local circulation which depends on the differences of temperature of air in different parts of the room.

The introduction of fresh air direct from the outside without warming it at all is altogether impracticable if draughts are objected to.

The details of different arrangements for warming air will be considered later. They may be classified as air-stoves, and batteries of hot water, or steam pipes. It is uneconomical to carry heated air any long distance, as the amount of heat conveyed per cubic foot of air raised to a given temperature is so small and so easily lost in transit. On this account Morin considers their availability limited to a horizontal range of 12 to 14 metres (40 to 45 feet), measured horizontally from the heating apparatus; it is preferable in a large block of buildings to carry the heat by means of water pipes and form local batteries of pipes whereby to heat the air immediately before it is

[1] *Manuel de Chauff.* &c. p. 186.

brought into use than to have a stove in the basement and distribute the heat by distributing the air supplied by the stove.

56. *Vitiation of Air by Heating Apparatus.*—In warming the air care must be taken to secure that it is not at the same time vitiated. It is a matter of common experience that if air is heated by being passed over a red-hot iron pipe it becomes 'burnt' and extremely disagreeable.

General Morin[1] has investigated the cause of the vitiation produced by iron, especially cast iron, when raised to a dull red heat. He shows that there is produced in the air an appreciable quantity of carbonic oxide—a highly poisonous gas—which results when coal is burned with insufficient oxygen, or when carbon dioxide gas is passed over red-hot coal or coke. It is to this gas that the poisonous action of charcoal braziers and coke fires is due. The presence of the carbonic oxide may be due to four independent causes, which may act concurrently, viz.:—

1. The permeability of the iron for this gas at high temperatures. If any carbonic oxide is formed in the stove some of it will pass out through the red-hot iron to the external air.
2. The direct action of the oxygen of the air upon the carbon of the cast iron.
3. The decomposition of the carbon dioxide gas of the atmosphere by the red-hot metal.
4. The incomplete combustion of organic dust floating in the air.

The production of carbonic oxide does not take place unless the iron is red hot. The air supplied for ventilation should therefore never pass over red-hot iron; all iron parts of a stove that are liable to become heated to redness should be lined with fire-brick or other refractory substance.

In such a case, evidently, no ventilation might be better than supplying the place of moderately foul air by air rendered poisonous by the presence of carbonic oxide, which is deleterious if breathed for a considerable time, even if in minute proportion.

Moreover, air passing over highly heated surfaces frequently acquires disagreeable properties which may be caused by the action of the heat upon the dust of the air, or that deposited upon the heating surfaces. These should therefore be so placed that they can be inspected and regularly cleaned.

57. *Humidity.*—When the external temperature is low, the air supplied will require to be moistened as well as warmed. The average humidity of air in these islands is about 75 per cent., so that the pressure of water vapour in the room must be about three-quarters of the saturation pressure indicated on the diagram on p. 46, or the pressure indicated by a point half-way between the corresponding points of the two curves there plotted. The diagram will also show what is the maximum possible vapour pressure in the external air at this temperature, and thus the necessity for moistening can be estimated. Part of the necessary moisture will be supplied by the actual respiration itself, but more may be, required which may be provided by injecting clean steam or water spray, or simply by exposing a water surface to the air.

3. *Positions of Inlet and Extract Flues*

58. The fundamental condition to be satisfied is that the air which leaves the room by the extract flues should be, in as far as there is any difference, the impure portion, as contrasted with the pure entering air.

The differences of detail which the problems in ventilation present make

[1] *Mémoires de l'Académie des Sciences*, vol. xxxviii. See *Manuel, &c.* p. 113.

it difficult to formulate any precise rules as to where the air should enter or leave the room in order that this condition should be satisfied, and authorities differ, to a certain extent, on the point. The main object of ventilation would be secured if the air which has been once respired were displaced in such a way that it cannot be again passed into the lungs, but is directly carried to the outlets. We cannot, however, treat each occupant of a room like a gas jet, and provide him with a separate exit pipe. The next best thing seems, at first sight at any rate, to get the exit pipes as near to the source of contamination as possible, so that the respired air may be forthwith removed. This plan is adopted with obnoxious gases produced on the table of a chemical lecture-room. An opening in the table provided with a strong down draught removes nearly all the offensive vapour in a very satisfactory manner, and some similar plan may be adopted with the auditory. The expired air is driven out through the nostrils and mouth with very considerable velocity, producing eddies and rapid mixture with the surrounding air, so that the upward force acting on the impure mixture due to the increase of its temperature is very small. The direction of projection of the air for a person sitting or standing (with the head in a natural position or inclined downwards as in writing) is downwards, so that by each act of expiration a person projects into the room a quantity of used air which mixes with the air of the room somewhat beneath his mouth, and this mixed volume, if left in still atmosphere, begins to rise but very slowly, and a very slight downward current is sufficient to carry it further downward. A number of persons sitting or standing together will produce a layer of impure mixture, and a general downward movement of very small velocity produced artificially will be sufficient to carry the layer of mixture below the heads of the persons, in spite of the upward effect produced by the natural heat of the bodies; so that in the case of a number of persons on the same level the most direct plan of carrying away the impure air is to establish a general downward current by means of outlets in or near to the floor. The total area of these outlets must be so great that there is no downward motion of the air perceptible as a draught in their neighbourhood. Similar considerations apply when the audience is arranged on tiers of seats, as in an amphitheatre. The position of outlets thus indicated is suitable for the cases of lecture-halls, concert-rooms (of not more than two floors), schools, churches, and chapels. The openings into the extract flue may be made under the seats either on the floor or in the risers of the seats at the back, and advantage should be taken of the erection of desks, book-rests, &c., to avoid the inconvenience of the openings being so near the feet as to cause a sensation of draught. Moreover, the openings must be very numerous and well distributed, and so proportioned in size that each one acts equally.

The entry of fresh air should be so arranged as to prevent local circulation and selective circulation, and to be sufficiently far away from the persons to avoid direct draughts. The most potent cause of local circulation in cold weather in churches and large halls is the large area of window space, and it would be well to fix the position of the warm air inlets with special reference to this point. It would probably be completely obviated by arranging a hot-air inlet a short distance under each window, and this position for inlets would seem in most cases to satisfy the conditions specified. In that case the descending cold air would have to be reckoned—partly at any rate—instead of fresh cold air taken from outside to mix with the warm air supplied. The cooling effect of windows can of course be reduced, as indicated on p. 41, by double glazing. If, by that means or some other, the windows may be left out of account—a circumstance of very

rare occurrence—the position of the inlets may be dictated by consideration merely of avoiding draughts and selective circulation. The outlets being at the floor level, the inlets should be well above the heads of the audience, and, if slightly colder than the air of the building, the incoming air should be directed upwards, if warmer, horizontally or slightly downwards.

For dining halls the case is somewhat different. The heat of the dishes and frequently of candles on the tables makes a much more intense local circulation, and exit orifices in the ceiling should be provided to meet the case. These may be in addition to or instead of the floor outlets already suggested. In considering the supply of fresh air, the space over each table must now be regarded as an upcast shaft of impure air which must be allowed to travel directly to the upper ventilators; the inlets may be therefore high up, in such positions as to avoid these rising columns of air, and in the ventilation system for this case we must make use of the local circulation and not simply trust to the motion of parallel horizontal layers of air.

The lighting of a room by gas requires special treatment. The gas produces local circulation, and if a separate extract flue is provided it is generally in a position most unfavourable for general ventilation; the whole air of a large hall must be very impure before a central chandelier is effective in removing impurity. Under low galleries the beneficial effect of a gas jet with separate flue is more direct provided that the inlets are so placed that selective circulation is avoided. Under the circumstances it is better to make the ventilation independent of the lighting arrangements, and to enclose the gas lights, as is done on the Wenham gas-light system and other regenerative gas burners, so that only as much air is supplied to the gas as is required for the combustion: this may be drawn either from the room or separately from the outside.

In theatres the problem becomes unusually complicated in consequence of the great intensity of the local circulations from the lighting and the proximity of many corridors and rooms, and the necessary smallness of the allowance of cubic space per head of the audience.

The arrangement proposed by Morin[1] includes a series of outlets in the galleries, the boxes, and the floor of the pit, and along the front of the stage, and inlets delivering into the area, between the joists of the floor of every tier, with special outlet for the gas chandelier.

The position of inlets for hospital wards requires also special consideration. General Morin ('Manuel,' p. 248) recommends them to be placed at the head of the beds at the *floor level*, but in the side walls, allowing at least one for every two beds in ordinary wards and one for every bed in wards requiring special ventilation. But De Chaumont (Parkes' 'Hygiene,' p. 186), on the ground that the breathed air rises rapidly, not only on account of its temperature but from the direction of projection, recommends that the point of discharge for patients in bed should be above, and the fresh warm air supplied from under the beds. In a plan said to be successful in America the outlets are under the beds and fresh air is supplied at the bed head to each patient. It remains probably still a matter of opinion which of these plans should be adopted. The reasons which we have given for placing the outlet at a low level in the case of a lecture-room or hall are not strictly applicable to hospital wards, as the beds form obstacles to the downward flow, and each patient might cause a local circulation that would interfere with the satisfactory working of the plan. Possibly outlets at middle height and inlets both at the top and bottom would satisfactorily solve the problem.

[1] See the diagrams for the Théâtre Lyrique and Théâtre de la Gaîté, *Etudes*, vol. i. plates xiv. xv.

4. *Provision of a Suitable Head for Extracts and Inlets. Correct Numerical Proportion between Areas of respective Inlets or Outlets.*

59. Three types of plan may be considered :

1. Injection of air by a blower from a central air chamber, leaving the air to find its way out of the outlets by the secondary head, due to increase of pressure in the system.

2. Suction by a single main shaft. The outlets in this case govern the head for circulation of the different rooms, and the air finds its way through the inlets.

3. Separate heads for the different outlets which act as upcast shafts, the head being due to the difference of temperature of the air in the flues and the external air.

Any particular case then may be a combination of two or more of these three types. The comparative advantages of the different methods will be treated later. What we now wish to point out is that in any case one of the conditions of success is that the head for any orifice, inlet or outlet, must be satisfactorily provided,[1] and the areas of inlets and outlets must not be taken at haphazard, and there must be a proper numerical proportion between the equivalent areas of the different orifices, the rules for the calculation of which are given above, § 20. If we have a main channel, A (fig. 42), with branch channels, A_1, A_2, A_3, A_4, the resistances of the channels must be arranged by adjusting the equivalent areas of the orifices, o_1, o_2, o_3, o_4, so that there is the same head for the flow required, between the rooms into which the orifices lead and the point A ; otherwise one of the channels will 'draw' more actively than the others. The area of the channel A must also be increased when a new channel joins it, so that the velocity of motion of the air may be kept nearly uniform throughout its length, and, further, when the ventilation is by a number of separate heads, the heads must be equalised, or at least sufficiently nearly so to prevent one overpowering the others.

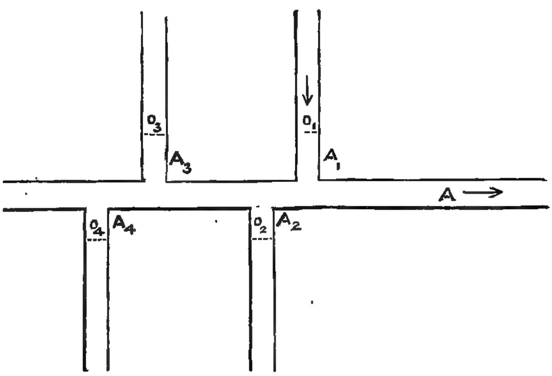


FIG. 42.

The areas of inlets and outlets must also be suitably related to each other. The area of one or other of the two is decided by calculation of the head required to produce the given circulation in the most economical manner. In calculating the head, taking for example the case of ventilation by an open fire, account must be taken of the loss in consequence of the friction of the inlets, and thence it follows that the greater the area of the inlets the better, so that the exact equality of area of the two is not a thing to be striven after for its own sake. What we mean by suitably proportioning them is that the inlets should be sufficiently large to secure that

[1] It seems hardly necessary to state that no efficient ventilation can be secured by any number of orifices unless there is an adequate head, but a recent experience in a room with an open chimney (without fire) and open window leads one to reflect on the improvement that might have resulted if a head had been established by putting a paraffin lamp in the fireplace.

the velocity shall not be too great. According to Morin ('Manuel,' p. 193), the velocity of efflux should be about three feet a second, and the velocity of influx two feet a second for inlets pointed downwards, and not more than three feet a second if pointed upwards or horizontally at a height of twenty feet above the heads of the occupants. If this rule be followed the inlet area must be capable of being one and a half times as great as the outlet.

5. *Completeness of Circulation*

60. In determining the plan of ventilation of a room the whole building must be treated as one system, and the plan of circulation drawn out for the whole. It is not sufficient to have a system which is only in working order for a room so long as all the doors are shut, if one of the conditions of the use of the room be that the doors shall be frequently open. This condition is especially peremptory in the case of domestic houses, and it practically amounts to requiring every outlet to be supplied with an adequate inlet, so that there shall be no head between different rooms. The ideal arrangement for a large building would be to combine the 'plenum' and 'vacuum' methods in such a way that there should be no head between the interior of any one of the rooms and the outside of the building.

APPARATUS FOR WARMING AND FOR COOLING

61. Hitherto we have been dealing mainly with the principles of ventilation and have assumed that the difficulties in the way were only those which arose from the unalterable properties of air and other materials that we had to deal with. We have supposed heat to be distributed wherever it was required and in whatever quantity. We have in fact disregarded the important practical details of the apparatus that must be used for the distribution of air or heat, and questions of expense or economy have not been dealt with. We now proceed, however, to consider more closely the practical side of the matter. We will deal first with the production and distribution of heat, although complete separation between warming and ventilating cannot be accomplished.

62. Artificial heat is produced, as we have seen already (p. 35), almost entirely by combustion. Different kinds of fuel differ considerably in the amount of heat which is developed by the combustion of a given quantity, and the prices of different fuels are also widely different. We give accordingly a table (after Morin) of the heat in lb. F. units developed by the combustion of 1 lb. of different kinds of fuel, and the number of lb. F. units of heat produced by the combustion of the amount in each case which can be bought for one penny at ordinary prices. It is of course a rough table, as the prices vary considerably in different localities.

TABLE VIII.

Fuel	No. of lb. F. units of heat produced by the combustion of 1 lb. of fuel	Price of fuel	No. of lb. F. units for one penny
Coal	14,000	20*s.* per ton	131,000
Coke. . . .	12,600	13*s.* 4*d.* per ton	176,000
Peat (dry) . .	9,000	1*d.* per 5 lb.[1]	45,000
Dry wood . . .	7,200	25*s.* per ton	54,000
Petroleum . .	21,000	10*d.* per gallon	17,220
Coal gas . . .	675 (per cu. ft.)	3*s.* per 1,000 cu. ft.	18,800

This table shows the total quantity of heat that is generated by the complete combustion of the fuel. Thus when a gas jet or petroleum lamp is burned in a room the table gives us the amount of heat supplied, all of which helps to warm the room in some part or other. The other fuels are now, however,

[1] Cambridge price.

always burned in stoves, with chimneys for carrying away the products of combustion, and every pound of fuel requires for its combustion a definite quantity of oxygen which must be provided by a constant supply of air to the stove. The oxygen that maintains the combustion takes with it into the fire the nitrogen and other constituents of the air, and these constituents which take no part in the combustion have to be removed with the carbon dioxide gas and water vapour which are the immediate products of the chemical action. The amounts of heat given in the table are calculated on the supposition that the inert gases and products of combustion leave the apparatus in which they are burned at the temperature at which they entered it, so that they carry away none of the heat which the combustion has produced. But this supposition cannot be realised in practical working; some heat is required to keep the air in the exit flue at a sufficiently high temperature to maintain steadily the requisite supply of air to the fire, so that, so far as the heating of the room or building is concerned, some heat must always be lost. With an open fire about nine-tenths of the heat of combustion disappear, being carried away partly by the heated products of combustion, partly by heated air which passes up the chimney without taking part in the combustion, and partly by conduction through the walls, as the fire is in general placed against the wall of the room.

63. To save some of the large margin of 90 per cent. of practically wasted fuel has been the object of very many inventions. We cannot attempt to enumerate them,[1] but we may classify them according to the direction in which they seek to limit the loss of heat. If we consider the action of an open fire it is evident that there are two ways in which heat passes into the room: (i) by radiation from the heated surfaces; (ii) by conduction to the sides of the grate, and thence by convection of the air in contact with it. Now with an ordinary grate the larger part of the heat which gets to the air by the second way is immediately carried up the chimney by the rapids of inflow of air to the chimney. It is, indeed, only the heated surface above the stove-opening which helps in any way (except by radiation, which for the parts heated by conduction is very small) to warm the room. The effect of an open fire must therefore be referred to radiation alone. Now the radiation varies very rapidly with the temperature of the radiating surface. The precise law is not accurately known, but is not ill-represented by assuming the quantity of heat radiated to be proportional to the fourth power of the temperature of the radiating surface, measured from 459° below the Fahrenheit zero. The result of this is that lowering the temperature of a surface 15° from 1000° F., or 1·5 per cent., will diminish the radiation by 6 per cent. Or, to give another example, suppose we had a red-hot ball at 1000° F., and brought into contact with it a second cold ball, and imagine that the heat of the one was instantaneously distributed between the two, so that we had two balls at 500° F. containing the same quantity of heat between them as the one had originally; the radiation from

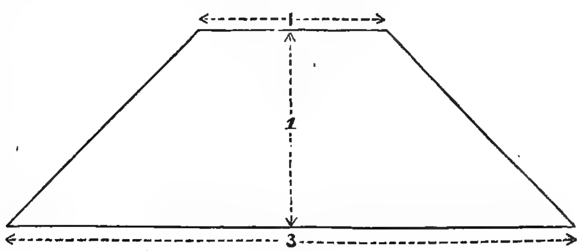


FIG. 43.

the *two together* would be $\frac{2}{5}$ of that from the one ball originally. Thus, if

[1] An abstract of patents for grates &c. compiled by Mr. J. Glaisher is included in the *Report of the Commission on Warming and Ventilation of Dwellings*, 1857.

without altering the total supply of heat we could so concentrate it that the temperature of the radiating surfaces was raised from 500 to 1000, the heating effect upon the room would be more than doubled.

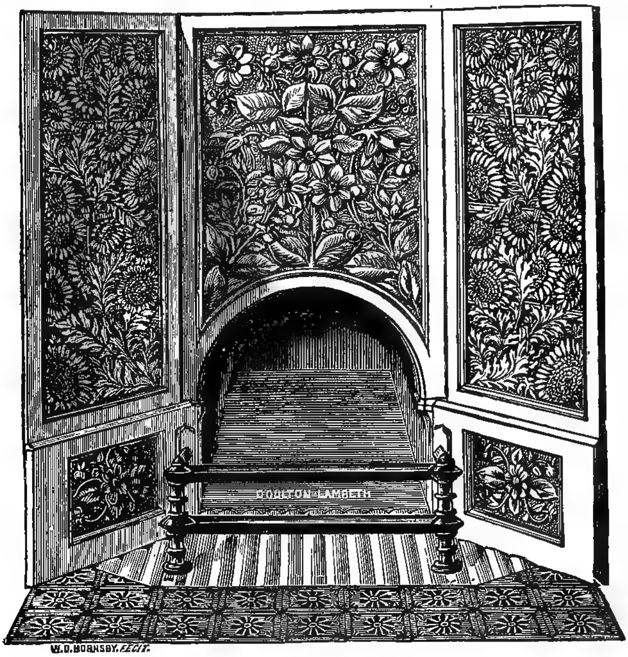


FIG 44.

(*a*) The first typical improvement in stoves will therefore be the provision for increasing the radiation from the burning fuel. Count Rumford long ago gave rules by which the shape of the stove should be regulated, viz. that the covings should be inclined at 135° to the back of the grate, and the 'register' door at the mouth of the flue inclined at the same angle. In this way some of the heat radiated from the fuel is reflected into the room and thus saved. The relative dimensions of the grate are given in fig. 43. The material of which the stove is made is also of importance. We have seen that it is advisable in order to promote radiation to limit the conduction, or insulate the heat, as much as possible. Referring to the table on p. 37 it will be seen that the stove should on this account be made of firebrick as far as possible, and the amount of metal reduced to a minimum. This point has not hitherto been much attended to by inventors, but the recent fireplaces of Messrs. Doulton (fig. 44) are constructed entirely of fireclay or pottery with the exception of a bar of iron in the front. Grates are, moreover, frequently made by simply fixing bars in brickwork, the sides of the brickwork being inclined to the back at nearly the angle suggested by Rumford, and their efficiency with a bright fire is very well recognised by common experience. Further im-

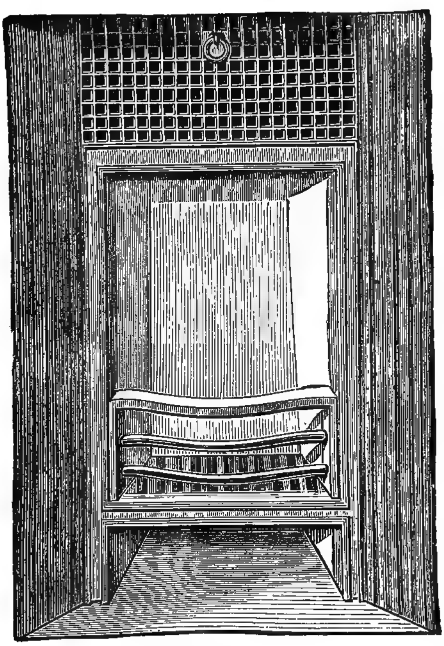


FIG. 45.

provement is secured by making the back of the grate of firebrick sloping forward to the throat of the chimney.

64. (*b*) The second type of improvement in open grates is that in which part of the heat which passes to the sides of the grate and the flue is brought into the room by surrounding the stove by an air space with two openings which communicate, one with the external air, and the other with the room. With these stoves the air which enters the room to replace that drawn by the chimney is warmed by the waste heat of the fire, and the communication established with the outside air affords a satisfactory inlet for ventilation purposes. Sir D. Galton introduced such ventilating stoves into the soldiers' rooms in barracks, and there are many kinds now in the market. The Doulton stove, above mentioned, can be provided with an inlet for air warmed by passing over the heated surfaces round the fire. This delivers the air to the upper part of the room. Boyd's Hygiastic grate (figs. 45–47) is constructed on this same principle, but delivers the air through an opening just above the fire under the mantel-shelf. By these devices about one-fourth of the waste heat can be utilised.

It is important that the air which enters by these ventilating stoves should not pass over any iron surface which is heated to a red heat for the reason given above, p. 118.

65. (*c*) The third typical modification of open grates refers to the economy of loss of heat by limiting the amount of air carried up the chimney without having taken part in the combustion. In order to reduce the loss from this cause attention must be paid to the shape and size of the chimney, for the head will be determined

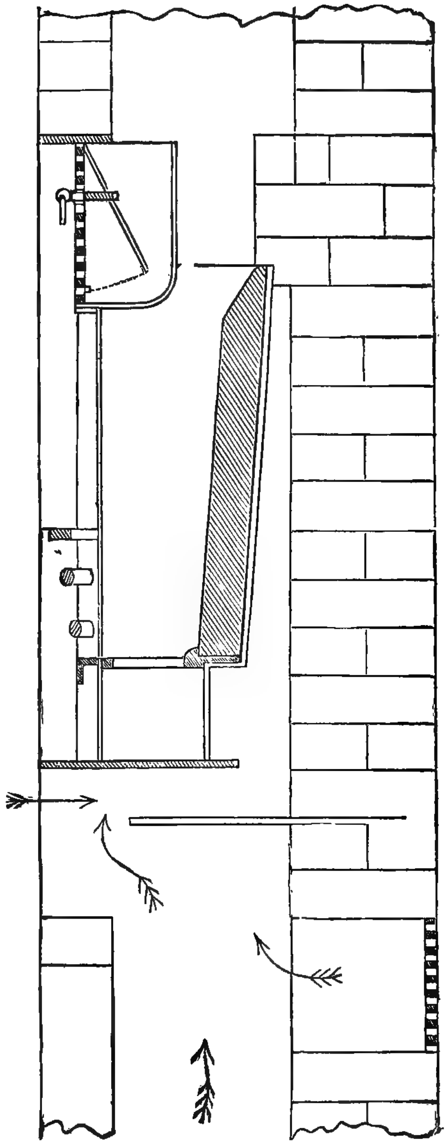


Fig. 46.

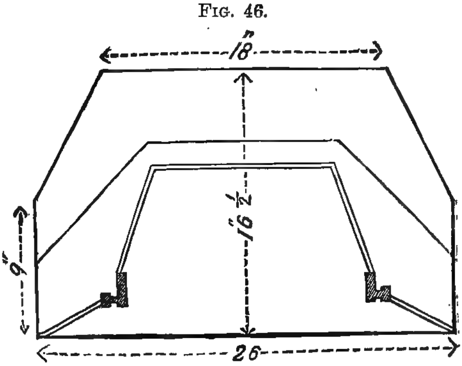


Fig. 47.

by the temperature of the air in the chimney, and the quantity of air which traverses it for a given head will depend upon the resistance of the shaft or upon the area of the equivalent orifice. The relation is given in § 17. The loss of heat can be restricted by narrowing the chimney and its orifices, but the removal of a certain quantity of air is desirable for the purpose of ventilation, and if the chimney-area is too much restricted, it will not carry away sufficient, so that the proper proportions of the chimney and its openings are to be determined with a view to the efficiency of the fire as a ventilating and warming apparatus combined. With this in view Morin[1] recommends that the temperature of the air in the chimney should be maintained at about 45° F. above the external air, and the velocity of the smoke issuing from the chimney should be about 10 feet per second, in order to secure stability in the draught, and that the chimney should be capped with a cone-shaped top—the area of the orifice of discharge to be one-half of that of the chimney (see p. 98). The chimney requires narrowing at the throat only if it is wider than necessary; in that case there is a danger of local circulation in the chimney itself, and consequent smoking, which is prevented by the increased velocity in the narrowed throat. The following table gives the dimensions of the chimney flues necessary for rooms of different sizes according to Morin:—

Table IX.

Relative Size of Chimney Flues for different Rooms

Cubic capacity of room in cubic feet	Volume of air to be removed by the chimney per hour in cubic feet	Area of section of rectangular chimney flue in square feet[2]	Diameter of section of cylindrical chimney flue in feet[2]
3,500	17,500	·99	·88
4,200	21,000	1·19	·98
5,300	26,500	1·48	1·08
6,350	31,750	1·78	1·21
7,750	38,750	2·17	1·31
9,200	46,000	2·57	1·44
10,600	53,000	2·97	1·54

When ventilating grates are used General Morin recommends the following proportions, 'Manuel,' p. 53.

Table X.

Table of Dimensions for Ventilating Grates (Morin)

Cubic capacity of room in cubic feet	Volume of air to be supplied per hour in cubic feet	Area of section of smoke flue in square feet[2]	Area of section of flue for the passage of fresh air in square feet
3,500	17,500	·54	1·5
4,200	21,000	·66	1·8
5,300	26,500	·81	2·3
6,350	31,750	·97	2·7
7,750	38,750	1·2	3·3
9,200	46,000	1·4	3·9
10,600	53,000	1·6	4·6

Close Stoves

66. If the fire is not required to assist materially in ventilation as well as in warming, very great economy can be secured in the consumption of fuel by inclosing the fire in a chamber so that the heat may be communicated to the walls of the chamber, and thence by conduction and convection to the air of

[1] *Manuel de Chauff.* [2] With a chimney-pot of half the area of the shaft.

the room to be heated. The air supplied to the fire is limited to that taking part in the combustion by closing the front of the stove, except that part which actually holds the fire, so that any air which passes in may be compelled to pass over the fuel; the stove stands out in the room and the products of combustion are led away to a flue by a narrow chimney of any required length. Such stoves are made of wrought iron, cast iron, or earthenware, and nearly all the heat which is produced by the combustion is used in warming the air surrounding the stove. The rapid distribution of heat is assisted in Sylvester's stove, which is of iron, by attaching to it a number of parallel iron plates.

Close stoves are sometimes surrounded with an outer envelope of iron or earthenware, and the heat of the stove is then used to warm the air in the space between the two chambers, and the air so heated is distributed as required. The arrangement is then known as a cockle stove. Large stoves on this plan are often used on the Continent for distributing warm air, and are known as *calorifères*. The air is in many cases merely taken from the chamber in which the stove is placed, and is liable to be very impure, but a connexion may be made directly with the external air, in which case fresh

TABLE XI.

Name of apparatus	Duty	Remarks
Ordinary grates	0·10 to 0·12	Remove air but do not provide for the introduction of fresh air. Warming healthy.
Ventilating grates	0·33 to 0·35	Remove air and introduce fresh air moderately warmed. Warming healthy.
Stoves:		
Earthenware for wood stove	·87	Do not remove enough air for healthy warming.
Gurney:		
Cast iron with flanges — coal	·90	
Cast iron with flanges — coke	·85	
Wrought iron — coal	·90	
Wrought iron — coke	·87	
Cast iron, with downward draught—coke	·94	
René Duvoir:		
Cast iron—coal	·86	
Compagnie d'Eclairage au gaz, without ventilation	·96	
Fireclay	·93	
Mean	·89	
Cast iron — Compagnie d'Eclairage au gaz, with ventilation	·85	Replace enough air for four or five persons.
Calorifères, with circulation flues for smoke — horizontal	·63	Cannot produce directly sufficient removal of vitiated air, and supply generally air too much heated, but could easily be modified to give air at 90°–120° F. Warming unhealthy when not combined with ventilation.
Calorifères, with circulation flues for smoke — vertical	·80	
Hot-water apparatus — With numerous coils of large area compared with the boiler	·65 to ·75	Suitable for establishing a regular system of ventilation.
Hot-water apparatus — When all the pipes &c. are contained in the rooms to be heated	·85 to ·95	

air is supplied ; but if the stoves are of iron the air is very frequently 'burnt' by passing over the red-hot iron surfaces, and the supply of fresh air by a stove of this form is therefore not satisfactory.

Moreover, according to Hood,[1] some of the close stoves are liable to develop explosive mixtures of gases and thereby originate fires. Fires have also arisen from the overheating of the flues, so that close stoves require to be worked with very great caution.

Table XI. of the preceding page gives a collective view of the efficiency or duty of the different kinds of stove investigated by General Morin and is taken from his 'Manuel,' p. 169. The numbers in the second column indicate the fraction of the total heat of combustion that is applied to warming.

Gas Fires and Gas Stoves

67. For general convenience there can be no question that the most suitable fuel is coal-gas. It can be ignited at any moment, the amount of heat produced can be adjusted to the amount required, it produces no dusty ashes, and can be very easily accommodated in any position. These advantages are enormous and will no doubt be more appreciated as the construction of gas fires is improved. Against them have to be set the disadvantages of the high cost of the heat derived from gas—about eight times that of the same quantity from coal—and the want of a cheerful appearance. Its efficiency as a ventilating extract flue is the same as that of a coal fire producing the same amount of heat. The cost of gas compared with that of coal is probably not yet at its lowest level, and may be expected to be lower when the producers feel the competition of the electric light. The objection to gas fires on the score of appearance can probably be considerably reduced by improvement in the designs of the apparatus. And from the circumstance that the appearance of a coal fire is due to red-hot surfaces and the flames of crude coal gas it seems that, with a combustible that will supply any required amount of heat and any required amount of light, some arrangement will be possible that is satisfactory, unless it be the very capriciousness of a coal fire that constitutes its main attraction.

In many gas stoves the necessity for keeping the radiation at a maximum by having only highly heated surfaces exposed to the room is not sufficiently recognised. They consist of a large mass of asbestos nodules heated throughout by the gas, giving a large body of heated matter with its exterior surface, from which the radiation mainly proceeds, comparatively cool. In such a case a larger fraction of the heat goes up the chimney than with a coal fire in good condition, and the contact of thick iron bars of an ordinary grate with the heated asbestos helps to depress the efficiency for radiation for the reason pointed out above (§ 63.) Gas fires should therefore be arranged so as to concentrate the heat upon as small a surface as possible, thus raising the temperature of the surface to the highest possible point. Some of the more recent gas stoves embody this principle, as the flame plays upon shreds of asbestos projecting from a fireclay back. Wright's stove is an example of this. It is arranged so that the heated products of combustion also pass over a series of tubes communicating with the outside air, and thus provides for a supply of warmed fresh air. The same arrangement is also provided in some of Fletcher's recent stoves, one of which is represented in fig. 48. George's Calorigen is another example.

[1] *On Warming Buildings by Hot Water &c.* p. 306.

With gas stoves as with coal stoves economy of heat is secured by arranging the apparatus so that it stands out in the room, and still further by limiting the size of the chimney flue and combustion area; but this economy is at the sacrifice of efficiency as a ventilating apparatus. As a general rule all gas stoves should be provided with an outlet flue for the escape of the products of combustion, which include, besides water vapour, carbon dioxide gas and a certain amount of sulphur dioxide gas due to the combustion of the carbon bisulphide which occurs as an impurity in coal gas. Of these products of combustion the last two seriously vitiate the air of the room, and the sulphur dioxide renders the air not only unhealthy, but perceptibly unpleasant by the sulphurous taste. The effect upon plants is very marked and very destructive, and traces of it can readily be found in leather bookbindings, which are rapidly destroyed, and brass work, which is rapidly blackened. Stoves have therefore been designed by which the most deleterious product is absorbed by water, or by the iron or zinc lining of tubes through which the products of combustion are led. The temperature of the burned gases is very much reduced by the same arrangement, so that a large part of the water vapour is condensed. Such stoves are therefore used for warming rooms without being provided with an exit flue, and the whole of the heat produced is retained in the room. It must, however, be borne in mind that the carbon dioxide produced by the combustion is not removed, so that the room should be well ventilated, otherwise it rapidly becomes unwholesome. In fact, such stoves are really only suitable for warming passages, lobbies, and other places where there is a considerable casual renewal of air, and persons do not remain for any length of time.

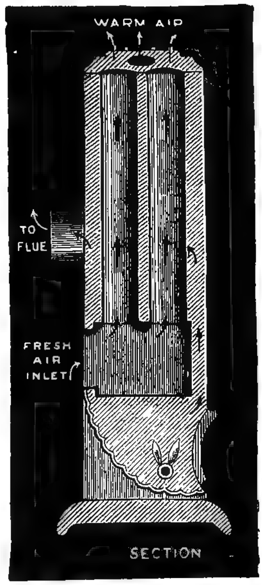


FIG. 48.

Some years ago Sir W. Siemens described in 'Nature' an arrangement for using coke ignited by gas in an ordinary grate in an exceptionally economical manner. Such a plan, which is intermediate between a coal fire and a gas fire, has considerable advantages.

Atmospheric Burners

68. The gas which is burned in stoves is now usually supplied through what we know as atmospheric burners, which may be either horizontal or vertical, the principle of which, the same as that of the ordinary Bunsen burner of the laboratory, is exhibited in fig. 49. The gas passes from the supply pipe

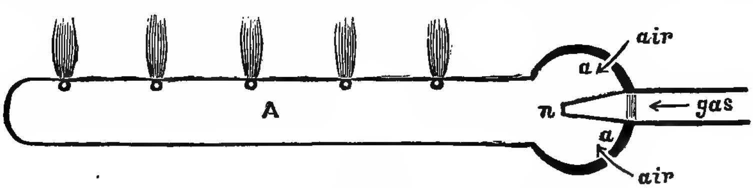


FIG. 49.

through a nozzle into a small chamber provided with perforations *a*, *a*, behind the nozzle, through which air passes; the air and gas mix in the comparatively wide tube A, from which the jets of gas pass by orifices *o*,

and are there ignited. If the supply of air is sufficient a flame which is non-luminous, or shows faintly blue, is produced; it gives rise to no smoke, and is much hotter than the ordinary illuminating flame of a gas jet in consequence of the more complete combustion of the gas, but it is liable to one serious drawback. If the supply of gas be too small the tube A becomes filled with an inflammable mixture of gas and air, which ignites, and the gas burns thenceforward at the nozzle *n*, producing an intolerable and easily recognised odour of half-burned gas, due to the hydrocarbons produced by the incomplete combustion. The gas will still burn at the orifice *o*, but with a languid, feebly luminous, and smoky flame, instead of the brisk blue non-luminous flame of the Bunsen burner in good condition. This 'burning down' always occurs if the gas supply is turned too low down, so that gas fires with atmospheric burners cannot be turned down to an unlimited extent. A reduction of the heat is generally better provided for by limiting the number of jets rather than the volume of any one jet. The 'burning down' also occurs if the pressure of the gas supply is too small or if the orifices be too large; the instability which accompanies this case is easily recognised by the roaring of the jets and the very marked cone of blue luminosity in the interior of the jet close to the orifice. When the flame is thus unstable the burning down occurs when the gas is exposed to a sudden draught. Any noticeable smell of half-burned gas from a gas fire should at once be met by an examination of the state of the jet. In order to set it right if it be burning at the nozzle the gas must be turned off completely and re-ignited at the proper opening.

Atmospheric burners are now made with devices for preventing the 'lighting-back.' One of the devices is to cover the openings at which the gas burns with wire gauze.

69. The volume of air drawn out of a room by a chimney is, according to Morin, 3200 to 4000 cubic feet per pound of coal burned with a chimney of average height (50 to 55 feet), and the volume required for combustion is 160 to 200 cubic feet. If gas is used for ventilation the relation between the amount of gas burned and the volume of air removed is given in the following table, taken from Morin, p. 198:—

TABLE XII.

Volume of gas consumed per hour in cubic feet	Volume of air passing up the flue per cubic foot of gas burned
7·1	1900 cu. ft.
14·1	1400 „
28·2	700 „
35·3	600 „
42·3	500 „
49·3	450 „

The gas was burned in a chimney about a foot wide. The table shows that the distribution of heat over a wide area is more effective for ventilation, and hence, for example, it would be better to double the area of section of a chimney and have two separate gas jets, than to combine the two jets into one, and so double the consumption of gas in the same chimney.

70. When it is proposed to warm a building by means of hot air provision must be made for maintaining a sufficient flow. The heated air naturally rises and may itself maintain the flow, if the room to be warmed be above the hot-water pipes or hot-air stove, and be provided with extract flues into which the warmed air ultimately passes. The supply of warm air can be more easily controlled if the extract flues are furnished with an independent supply

of heat, as by means of gas jets burning in them, or by using as extract flues the chimneys of open fireplaces with small fires not themselves sufficient for the satisfactory heating of the room. In such cases the total supply of air to the room is governed by the draught of the extract flues, and warmed air, or cold, can be supplied by suitable arrangements as occasion may require. If we take the case of an ordinary house we may regard each fire as requiring about 15,000 cubic feet per hour, usually supplied through casual orifices direct from the outside air, but, if a special fresh air inlet be furnished, terminating in a case of water pipes in the hall, the air supply to the fires will be drawn in great part from this inlet, and the whole house will in this way be continuously supplied with moderately warmed air. It need not be supposed that the heat thus communicated to the entering air passes directly into the rooms where the fires are; on the contrary, the heated air causes a very vigorous local circulation up and down stairs and makes an extensive tour of the house before reaching the chimney by which it escapes again to the outside. I have found a fresh-air inlet such as here described delivering 22,000 cubic feet of air per hour into a house to feed fires in three rooms. It need scarcely be remarked that in warming by hot air the object aimed at should be to supply a large quantity of moderately warmed air and not a small quantity at a comparatively high temperature. Some systems of hot-air warming are very defective from this point of view. Instead of providing active extract shafts, the air may be driven over the heating coils by means of a fan if satisfactory arrangements can be made for driving it.

On the Distribution of Heat

71. We have been considering in the preceding paragraphs the various ways of producing heat and the economy of production; the next question to be considered is the method of carrying the heat from one central furnace to rooms more or less distant from the furnace. The different plans which have been tried may be enumerated as distribution by circulation of hot air, water at low pressure, water at high pressure, and steam, respectively.

Distribution by Hot Air

72. This system is frequently employed with calorifères or cockle stoves. Tubes are carried from the air chamber surrounding the furnace; the circulation is maintained by the head, due to the difference between the temperature of the air in the delivery flues and that of the air as it enters the supply inlet of the stove. It follows that the furnace must be at the bottom of the system for the supply of hot air. The laws which govern the circulation of air in the flues have been given (§§ 14–21). The amount of heat which a given quantity of air carries is very small, so that it must be raised to a very high temperature if any considerable distance has to be traversed, and the loss in transit is very large; it is therefore only a suitable method for local distribution.[1] The heat for a large hall or series of rooms, for example, should be carried by water to a battery of hot-water pipes in a hot-air chamber near the rooms, and the distribution of the heat from the battery of pipes effected by air passing from the hot-air chamber through comparatively short channels to the inlets of the rooms. Care must be exercised in forming the channels to be used for hot air, as they are liable to warp and crack in consequence of the drying effect.

[1] See p. 117.

Distribution by Water at Low Pressure

73. This method is one which is very frequently employed for distributing heat in large buildings. The distribution is effected by the circulation of water in metal pipes—generally cast iron—one part of the circulation system being a boiler which is kept at a high temperature by a furnace. Representing the circulation diagrammatically (fig. 50), we may regard it as consisting of two vertical tubes HB, H′L connected at the top by a horizontal tube HH′. The bottom end, L, of the vertical tube H′L is connected with the bottom of a boiler at L′, and from the top of the boiler a tube, BH, passes. At the highest point of the circulation is an air-vent, A, open to the atmosphere, so that the pressure at any point of the circulation exceeds the atmospheric pressure only by the pressure due to a column of water whose height is equal to the vertical distance between the point A and the point at which the pressure is required. Thus the pressure in the boiler will increase by ·43 lb. per square inch for every foot of vertical height of the circulation

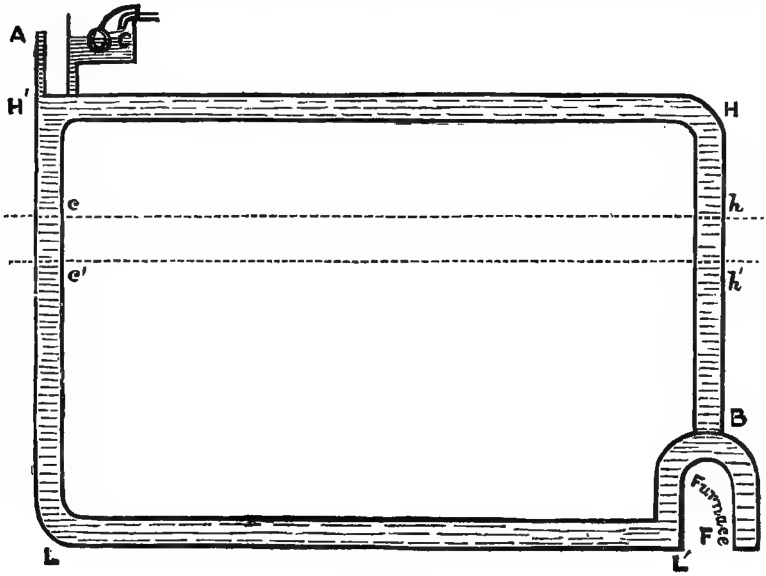


FIG. 50.

above the boiler. If we take the extreme case of a circulation 100 feet high the pressure in the boiler will exceed the atmospheric pressure by 43 lb. per square inch. Now the temperature of water cannot exceed a certain point, depending on the pressure, without producing steam; the temperature for a pressure of 43 lb. in excess of the atmospheric pressure is 290° F., or only 78° above the ordinary boiling-point. If the temperature in the boiler exceeded this, when it was supplying a circulation 100 feet high, steam would be formed, which would pass up the vertical pipe and condense with considerable noise and tumult in the cooler water until it had heated the whole upper part of the circulation sufficiently for it to escape as steam at A. This formation of steam in hot-water pipes is not allowable, so that the furnace must not be stoked so as to heat the water in the boiler to that temperature. And hence the highest temperatures possible in a circulation open to the air at one point, is 212° at the top, and increasing (not, however, proportionately to the depth) until at a depth of 100 feet below the

top it may possibly reach 290° F. As 100 feet would be a very exceptional height, we may say that the temperature of water in low-pressure circulation will not generally exceed 212°. This is the characteristic which distinguishes it from the high-pressure water system.

It is essential that the circuit of water should be complete; an accumulation of air in the pipe entirely stops the flow, so that a vent for air must be provided at the top, and wherever air would naturally be imprisoned when the pipes are filled with water from the top. Water, on being heated, disengages a very large quantity of dissolved air, so that these air-vents will always be required to be open from time to time when the pipes have been filled with fresh water after being emptied. It is moreover necessary to provide for the expansion of the water, so that it is usual to place at the top of the system of pipes a small cistern, C, into which the water driven out by the expansion can pass without causing an overflow; and the same cistern may be employed to fill the pipes and automatically replace the water lost by leakage if it be provided with a water supply and ball-tap. Of the two pipes connected with the boiler, BH is called the flow-pipe and LL′ the return-pipe.

74. The calculation of the flow of water in the circulation is very similar to that of air already considered. The head is due to difference of density of hot and cold water, and may be calculated as follows. Consider the two portions of the two vertical tubes contained between two horizontal planes, hc, $h'c'$, one foot apart; let ρ be the density of water between h and h', ρ' that between c and c'; the pressure due to the height hh' is $(hh')\rho$ lb. weight per square foot, and that due to cc' is $(cc')\rho'$ lb. weight per square foot, and the difference of pressure for that foot of the vertical height of the circulation is

$$(cc')\rho' - (hh')\rho,$$

and the work done by the difference of pressure for the passage of V cubic feet

$$V\{(cc')\,\rho' - (hh')\,\rho\}.$$

The head is therefore $\{(cc')\,\rho' - (hh')\,\rho\}\rho_0$, where ρ_0 is the standard density at the freezing-point. But $\rho' = \rho_0\,(1 - at')$ and $\rho = \rho_0\,(1 - at)$, where a is the coefficient of expansion of water.[1] Hence the head for one foot $= a\,(t - t')$ (since cc' and hh' are each equal to one foot), or the head per foot per unit difference of temperature is equal to a.

Hence, to find the head for any circulation, we may divide the circulation into foot sections by parallel horizontal planes one foot apart. Measure the temperature at each section of the flow and return-pipes, and the head of the whole circulation is the sum of the differences of temperature of corresponding sections multiplied by the coefficient of expansion of water. If the total sum of the differences of temperature comes out negative it shows that the circulation is in the opposite direction.

The temperature at different points of the circulation may be approximately determined by placing a thermometer on the pipe and wrapping it round with a good thickness of cloth or felt.

[1] For the sake of simplicity we have assumed that the coefficient of expansion of water is the same at all temperatures. This is not really the case. In fact, water contracts slightly when it is heated for the range of temperature between 32° F. and 39° F., and on further heating it expands, at first very slightly and then to a gradually increasing extent, until the expansion of a cubic foot for the ten degrees below the boiling-point is ·0042 cu. ft. The temperatures in the flow and return pipes of a hot-water circulation will not be far outside the limits of 92° F. and 212° F., and the mean coefficient of expansion for this range is ·000318, which may be taken as the numerical value of a in the expressions in the text.

The head depends upon the vertical height, so that an inclined pipe with a gentle slope or a coil of horizontal pipes is only effective to the extent of its vertical height.

If the horizontal planes cut the pipes in more than two points, as in fig. 51, at h_1, h_2, h_3, h_4, the head may be calculated as before, separately for the two portions h_1 and h_2, and h_3 and h_4 respectively, so that the head due to the section represented will be, if t_1, t_2, t_3, t_4 be the corresponding temperatures,

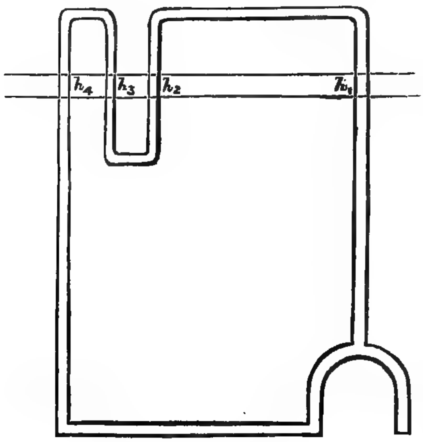


FIG. 51.

$$(t_1 - t_2 + t_3 - t_4)\ a,$$

from which it will be seen that the introduction of a depression such as that represented in the figure reduces the head by the sum of the products $(t_2 - t_3)\ a$ for each vertical foot of height of the depression introduced.

The calculation of the head in this manner will make it easy to see from a diagram of the proposed position of water-pipes whether there will be a flow, and in what direction, and will suggest the most advantageous way of arranging the pipes so as to produce the maximum head. Thus, in carrying a circulation below the boiler, as shown in fig. 52, it will be seen that the head due to the part of the circuit above the horizontal line, hh', is opposed by that due to the rest of the circuit, so that if the fall of temperature were simply proportional to the length of the pipe traversed the circulation in the circuit represented would be reversed. But if it be arranged so that there is a considerable loss of heat from HH′ and consequent fall of temperature between H and H′, and if the heat required be taken from coils on the part of the circulation represented by HL, and as little as possible from the part leading from L back to the boiler (indeed, the pipes may be so arranged that part of the heat lost from h'L warms L′h, by passing L′h through the heating coil on H′L), the circulation may be established, though carrying pipes below the boiler is not always a successful arrangement; and in order to secure a flow it may be necessary to waste a good deal of the heat in cooling the part represented by HH′.

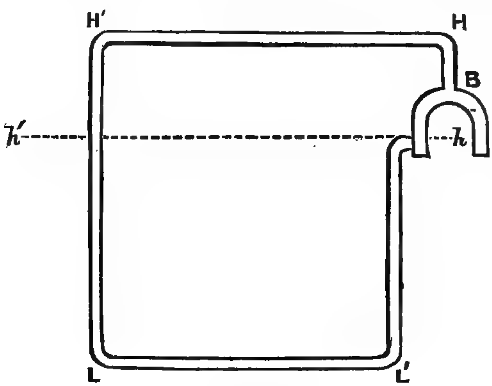


FIG. 52.

Wherever there is a head, great or small, there will be a flow of some sort, provided there is a continuous channel filled with water from the boiler, and back again. The magnitude of the flow as measured, say, in cubic feet of water per minute depends, just as in the case of air, not only upon the head, but upon the resistance of the complete channel. The

resistance could be calculated by laws similar to those we have explained for air, but the calculation for any hot-water system would be exceedingly elaborate and complicated, so that hot-water engineers work empirically from established successes to any new arrangement required.

75. Difficulties sometimes arise when a number of circulations have to be maintained by the same boiler, for if the circulations supply pipes on different levels the head for each circulation will be different, and the object desired is that the flow shall be the same for each; but this can be adjusted by means of a valve upon each separate circulation by which the circulation with a greater head can be 'throttled'—that is, have its resistance artificially increased. The plan is, however, not without its disadvantages, for it of course implies reducing all the flows to that in the circulation with the worst head. It is therefore desirable, if it be seen that the head for any circulation will be small, to make its resistance comparatively small also, so that the other circulations need not be throttled.

High-Pressure Water System

76. We have seen that if one part of a circulation have free access to the air the temperature of the water cannot rise much beyond the boiling-point at ordinary pressure, viz. 212° F. But if the water be completely inclosed the temperature can be raised to a very much higher figure, and the pressure exerted upon the pipes is more than proportionately high. Thus the pressure of steam, or the pressure required to prevent steam forming at 212° F., is $14\frac{3}{4}$ lb. per square inch, at 300° F. it is 67 lb. per square inch, and at 400° F. 250 lb. per square inch.

A system of heating by water pipes has been designed and worked by Messrs. Perkins in which the pipes are of wrought iron and sufficiently strong (internal diameter $\frac{7}{8}$ inch, external $1\frac{5}{16}$ inch) to withstand the pressure corresponding to very high temperatures.

A sufficient length of these narrow iron pipes connected by an ingenious device is formed into a complete circuit; part of the circuit is coiled into a hollow coil and exposed to the heat of a furnace. At the top of the circulation is a series of tubes of larger diameter, called expansion tubes, half filled only with the water, the other half with air, and therefore allowing for the expansion of the water. When the pipes have been filled with water the openings at the top are closed by screw plugs, so that the whole system forms a closed vessel with a small quantity of air at the top, which does not, however, extend so far as to impede the circulation of the water. The water circulates with very great rapidity in spite of the narrowness of the bore, and when the apparatus is in full working the temperature of the pipes reaches, as a rule, 300° F.

The temperature is regulated by fixing the proportion of length of pipe in the furnace to the length outside; it is usually one-tenth. If the space to be warmed is too large to be heated properly by a single flow and return, the pipe is carried back to the furnace and a second coil made, and then the pipe proceeds again to another part of the building and returns to be connected with the end of the first circulation. This may be repeated several times, so that the pipe may start from the furnace and return to it again, start again, and come back, four or five times before the circuit is complete. In general, a circulation with one coil only in the furnace consists of 1500 feet, 150 feet being exposed to the fire; if a second 1500 feet are required the circuit includes another 150 feet in the fire, and so on. Thus the same water passes through the whole length of pipe, however great it may be, but, generally, not more than 7500 feet are heated by a single furnace.

The water in the pipes wastes to a certain extent, although the whole is closed up, so that the plugs at the top are periodically taken out and a little water added.

The high temperature of the pipes, though useful and desirable from the fact that the distribution of heat takes place to a greater extent by radiation than is the case with low-pressure systems, requires that the system should be introduced with proper precautions. The insurance companies require the pipes to be at least one inch from the woodwork, and this is no doubt generally desirable and should be provided for. Should a pipe for any reason become stopped, the pressure reaches an uncontrollable magnitude, but the weakest part is that in the fire, so that it bursts there, and the fissure is said to be so small that the water issues as a jet of steam without doing any serious damage.

Distribution of Heat by Steam Pipes

77. There are many plans for keeping a series of pipes hot by the circulation of steam, and they differ in the form of the pipes and the pressure of the steam employed. If the system is well arranged the heat is developed by the condensation of the steam, and no steam leaves the pipes but only the condensed water, which may be returned to the boiler by suitable apparatus. The condensation of the steam causes a rattling noise in the pipes which is sometimes disagreeable. The pressure of steam in the pipes is in any case limited by the safety-valves of the boiler, but when low-pressure steam is required from a high-pressure boiler a reducing valve may be introduced. For further information the reader may be referred to a paper 'On the American Practice of Warming Buildings by Steam,' by the late Robert Briggs ('Proc. Inst. C.E.' vol. lxxi. 1882–3, p. 95, with the discussion thereupon).

Amount of Heating Surface Required for Warming Buildings

78. The calculation of the amount of hot-water piping of given external diameter that may be necessary for the adequate warming of a building depends upon a large number of elements. Provision must be made for the loss of heat by conduction through the walls and windows, as well as for that carried away by the air in the process of ventilation. Both these are variable quantities depending upon the state of the weather; moreover, in calculating the former, the nature and thickness of the walls and the area of window surface must be known, and for the latter more heat will be required, if for any reason the ventilation flow is more active, and less if the ventilation is restricted. We have not space to indicate the details of the calculation in special cases. An additional disturbance of the calculation is introduced if a room is occupied by a large number of persons or if artificial light is employed. It must be assumed that the amount of heat available shall be sufficient to raise the temperature to the highest point required in the coldest weather likely to be experienced, and with the fullest ventilation which the circumstances require. The supply can then be restricted by a valve on the apparatus if the conditions are such that a reduction of temperature is desirable.

In order to enable the reader to determine approximately the length of low-pressure water pipe required, we give a table from Hood's 'Warming of Buildings,' p. 119, showing the length of 4-inch pipe at 200° F. necessary to warm given quantities of air. If the diameter of pipe is increased in any ratio the length required will be reduced in the same ratio. Thus 200 feet of 4-inch pipe can be replaced by $\frac{4}{3} \times 200$ feet of 3-inch pipe and so on.

'The quantity of air to be warmed per minute in habitable rooms and n public buildings must be from three and a half to five cubic feet for each person the room contains, and one and a quarter cubic foot for each square foot of glass.'

If the high-pressure system is employed, the necessary area of surface is very much reduced in consequence of the higher temperature which is reached.

TABLE XIII

Showing the Length in Feet of Pipe, 4 Inches in Diameter, which will heat 1000 *Cubic Feet of Air per Minute any required number of Degrees, the Temperature of the Pipe being* 200° *Fahr.* (Hood.)

Temperature of external air, Fahrenheit's scale	Temperature at which the room is required to be kept									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
10°	126	150	174	200	229	259	292	328	367	409
12°	119	142	166	192	220	251	283	318	357	399
14°	112	135	159	184	212	242	274	309	347	388
16°	105	127	151	176	204	233	265	300	337	378
18°	98	120	143	168	195	225	256	290	328	368
20°	91	112	135	160	187	216	247	281	318	358
22°	83	105	128	152	179	207	238	271	308	347
24°	76	97	120	144	170	199	229	262	298	337
26°	69	90	112	136	162	190	220	253	288	327
28°	61	82	104	128	154	181	211	243	279	317
30°	54	75	97	120	145	173	202	234	269	307
Freezing point 32°	47	67	89	112	137	164	193	225	259	296
34°	40	60	81	104	129	155	184	215	249	286
36°	32	52	73	96	120	147	175	206	239	276
38°	25	45	66	88	112	138	166	196	230	266
40°	18	37	58	80	104	129	157	187	220	255
42°	10	30	50	72	95	121	148	178	210	245
44°	3	22	42	64	87	112	139	168	200	235
46°	—	15	34	56	79	103	130	159	190	225
48°	—	7	27	48	70	95	121	150	181	214
50°	—	—	19	40	62	86	112	140	171	204
52°	—	—	11	32	54	77	103	131	161	194

To ascertain by the above table the length of pipe which will heat 1000 cubic feet of air per minute, find, in the first column, the temperature corresponding to that of the external air, and at the top of one of the other columns find the temperature at which the room is to be maintained; then, in this latter column, and on the line which corresponds with the external temperature, the required number of feet of pipe will be found.

We quote also from the same work (§ 111) some empirical rules, giving the length of 4-inch pipe required for rooms of different sizes and character. We have omitted the footnotes which apply to certain special cases.

'*Churches and large Public Rooms*

'To heat these when they have an average number of doors and windows, and only moderate ventilation, divide the cubic measurement of the building by 200, and the quotient will be the number of feet in length of pipe four inches diameter that will be required to produce a temperature of about 55° in very cold weather. This is equivalent to allowing five feet of 4-inch pipe for every thousand cubic feet of space which the building contains. If the apparatus is so contrived that the warming of the air is effected before it actually circulates in the room, and that the same portions of air are not returned to be heated a second time, but fresh portions of external air are brought successively in contact with the heating apparatus, it will require from 50 to 70 per cent. more pipe to produce the same effect; but the air will, of course, be more pure and fresh.

'*Dwelling-rooms*

'These will generally require about twelve feet of 4-inch pipe to every thousand cubic feet of space contained in them to give a temperature of about 65°. To raise the temperature to 70° will require about fourteen feet of 4-inch pipe.

'*Halls, shops, waiting-rooms,* &c. will require about ten feet of 4-inch pipe to every thousand cubic feet of space to raise the temperature to about 55°. For a temperature of 60° about twelve feet of 4-inch pipe will be required.

'*Schools and lecture-rooms*, requiring a temperature of 55° to 58°, will require from six to seven feet of 4-inch pipe to every thousand cubic feet of space.

'*Drying-rooms*, or closets for drying wet linen and other substances, require from 150 to 200 feet of 4-inch pipe to every thousand cubic feet of space to raise the temperature to 120° when empty, or about 80° when the room is filled with wet linen.

'*Drying-rooms* for curing bacon, or for drying paper, or leather, or damp hides, will require twenty feet of 4-inch pipe to every thousand cubic feet of space to give a temperature of about 70°.

'*Greenhouses and conservatories* requiring a temperature of about 55° in the coldest weather must have thirty-five feet of 4-inch pipe for each thousand cubic feet of space they contain.'

Warming Apparatus in Relation to Ventilation

79. Heat may be used in two ways in a ventilation system: first, to produce a head in an outlet flue for the extraction of air, and secondly to warm the air of the rooms or that supplied to the inlets. We have sufficiently dealt with the first application of heat. As to the second, we merely wish now to remark upon the effect of the warming apparatus upon the state of the air. We have already (§ 56) pointed out a danger in the case of iron stoves, and the remarks in Table XI. § 66 indicate the healthiness or otherwise of the systems of warming there referred to.

The air which is warmed by passing over heating surfaces of any kind is dried in consequence, and this effect, being dependent only upon the extent to which the temperature is raised, is the same whatever system of warming be adopted, and can only be counteracted by furnishing the air with an additional supply of moisture. The hot-water systems and steam-heating systems should not of themselves deteriorate the air which they warm, but the pipes which carry the water or steam are generally put in out-of-the-way places, which are very liable to become receptacles for dirt of one sort or another. A considerable accumulation is likely to take place during the summer months when the apparatus is not in use, and when the pipes are heated for the winter the dust becomes subjected to a process of distillation, and the air is consequently fouled. The pipes should therefore be laid in such a manner that they can be periodically and properly cleaned. The injurious action upon the air depends, other things being equal, upon the temperature, so that the high-pressure system is likely to cause greater annoyance in this respect than the low-pressure pipes; but if the pipes are properly cleaned there seems no reason to anticipate the fouling of the air by either system.

What is here said about hot-water pipes applies to a modified extent to all channels for the supply of fresh air. They are always liable to be fouled,

and require cleaning, and if the openings are covered with gauze or gratings the deposit of dirt there may seriously interfere with the supply of air, both as regards its quantity and its quality.

Artificial Cooling

80. A corollary to the general problem of maintaining the air of an inhabited room at the temperature most suitable for its occupants is the consideration of the means of reducing the temperature in summer if the weather should render such a reduction desirable. In an early section (§ 6) we considered the means of preventing the communication of heat between a room and the external air, but the only special precautions in general use to prevent a too high temperature in summer are to shut the windows and cover them with outside blinds, or louvre shutters, to prevent the direct radiation of the sun from penetrating to the room, and to whitewash the roofs, in order that the heat of the sun's rays may be dissipated by the diffuse radiation from the white surface. The effect of the first precaution is most easily apparent; what the effect of the second may be it is difficult to estimate, except in a most general way.

Another method of keeping a room cool in summer is to supply it with air which passes through an underground channel; but such a method is not often adopted, and the air is likely to be fouled, even to the extent of having a mouldy smell, unless special precautions are taken to keep the channel dry and clean.

If the outside air is dry, it can be cooled considerably on its passage into a room by being made to pass over wet surfaces of linen &c. or by the injection of water spray. The cooling in this case arises from the evaporation of water into the comparatively dry air, and the water so evaporated is carried by the passing air into the room to be cooled. The air is thus nearly saturated by the cooling process, and the moistening may easily be carried further than is generally desirable. But on this point it must be remembered that any cooling of air necessarily causes it to approach the saturation point (see p. 45) unless moisture is abstracted when the cooling is effected.

81. Of late years there has been a great development of machines for the artificial production of ice or the supply of cold air. Such machines may be arranged in three classes:—

(1) *Machines in which the cooling is produced by the evaporation of a volatile liquid in one vessel, the vapour formed being absorbed by water or some other liquid in another vessel connected with the first*

Carré's ammonia machine is one of the best known examples of this method. A solution of ammonia gas in water is first placed in a vessel, which we may call a boiler, and the boiler is connected with a second vessel, a condenser. The boiler is first heated to about 250° F. and the condenser meanwhile cooled by immersion in a water tank; the ammonia is driven off from its solution and the pressure reaches so high a point that the ammonia gas condenses to a liquid in the condenser, giving out a large quantity of heat in so doing to the water of the tank. The apparatus is then removed from the furnace and the tank; the boiler is next immersed in water, and the condenser is surrounded by the water to be frozen. The cooled water in the boiler reabsorbs the ammonia vapour and reduces the pressure, and thus determines the evaporation of the ammonia liquid and a consequent large reduction of temperature in that liquid and the vessel which

surrounds it. By repeating the process successive quantities of heat are removed from the vessel surrounding the condensed ammonia. With a large apparatus of this kind, arranged for continuous instead of intermittent cooling, ice is said to be producible at the very low rate of twopence per hundredweight. (Peclet, 'Traité de la Chaleur,' tome iii. p. 149.)

Another of Carré's apparatus in which heat is absorbed by the rapid evaporation of water at low pressure, the vapour being absorbed by sulphuric acid, is also an example of this type of machine.

(2) *Machines in which cold is produced by the expenditure of mechanical work in the evaporation of a liquid*

We have already seen that water evaporates at all temperatures; the amount of evaporation depends upon the pressure to which the surface is exposed. The same is true of other liquids, and advantage is taken of this in the production of cold or abstraction of heat. The rate of evaporation is very slow if there is any considerable pressure of air on the surface of the liquid, so that the first step in the manipulation of an apparatus of this kind is to pump out the air. If we suppose the air removed, we may consider two vessels which are, so to speak, in communication through an air-pump, that is to say, as the pump is worked any air or vapour in the one vessel will be gradually pumped out and delivered to the other. The result is that if a volatile liquid be contained in each of the vessels the vapour will be pumped from the one vessel to the other, and, in consequence, continuous evaporation will take place in the one vessel and continuous condensation in the other. This implies a continuous absorption of heat for the formation of vapour in the one vessel and a continuous development of heat by condensation in the other. Thus by keeping the pump working heat passes from the cold evaporating liquid and its surroundings to the hotter condensing liquid and its surroundings. By adding some arrangement for the transference of the liquid back to the evaporating vessel the process may go on continuously. Such an apparatus can therefore be used either as a cooling apparatus or as a warming apparatus, whichever may be desired.

If heating is wanted, the cold vessel should be surrounded with an ample supply of water to keep up its temperature; if cooling is desired, the heat developed by the condensation may be thrown away by allowing it to pass into the outside air or a tank of water. This is one instance already alluded to of the employment of mechanical work (viz. that required to work the pump) for the purpose of heating or cooling. But an important and interesting point in connexion with it is that the heating effect is greater than the mechanical equivalent of the power employed to drive the pump. In fact, neglecting losses, the heat which is given to the condensing vessel is greater than the amount equivalent to the work done in pumping, by the amount drawn from the evaporating vessel. An ideal arrangement, as suggested by Sir William Thomson, would be to make use of both the heating and cooling effects of such an arrangement; suppose, for instance, that an arrangement of this kind were used for warming a house in winter, then it might at the same time be producing ice, which could be stored in a suitable ice-house for use in summer, and we should thus be able, in a sense, to equalise the distribution of summer and winter temperature inside the house by localising the loss of heat in winter, and storing it, so to speak, in the ice.

But we are not aware that this ideal arrangement for using both ends of a mechanical heating and cooling apparatus has ever been put into practice.

The one end of it, the cold producer with methylic ether as the evaporating liquid, has, however, found application on a commercial scale. It is one of the methods used in the cooling of ships employed for the carriage of meat. By the cooling apparatus the meat is kept in a current of dry air very near the freezing-point, and is thus kept fresh during long voyages. An apparatus by MM. R. Pictet et Cie., with sulphurous acid as the evaporating liquid, was used to cool glycerine to such an extent as to freeze the surface of water of an artificial ice skating rink. The price assigned to the production of ice on a large scale by this apparatus is fourpence per hundredweight.

(3) *Machines in which cold is produced by the expansion of air*

The dynamical cooling of air has already been referred to and accounted for. The considerable fall of temperature corresponding to the expansion of air from considerable pressures to the atmospheric pressure shown in the table of page 43 shows that if this expansion could be arranged on a large scale cooling could be effectively carried on. The air must not, however, be allowed simply to blow out through a fine nozzle, for in that case the fall of temperature would be greatly reduced in consequence of friction at the nozzle. It is, in fact, desirable to pass the compressed air through an engine, and let it do some such work as pumping water, or driving a knife machine, a shoe-blacking machine, or an electric-lighting dynamo,[1] in order that the greatest effect may be produced. As we have to start with uncompressed air it would be necessary for the installation of a cooling apparatus on this plan to provide for the compression of the air by a second engine; the compression would heat the air, and the heat so generated is a waste product of the cooling apparatus, but might be employed in heating buildings while ice was being produced by the expansion; and we should thus get an arrangement similar to that indicated for the evaporation machines in which the whole plant would consist of a compressing engine, delivering hot compressed air which may be cooled and then passed into an expansion engine, which delivers the air cooled to an extent depending on the difference of its pressure in the compressed and uncompressed states. But the supply of compressed air at ordinary temperatures to houses and workshops is now becoming a commercial matter in some large towns, just as the supply of gas or electricity has become; and in that case the householder requires only an engine providing for the expansion of the air and performing the useful work indicated above, in order to get ice-cold air, and so produce ice itself if it is wished. A most interesting account of the way in which such a system of distribution of compressed air is employed in Paris (Popp's system) is given by Professor A. B. W. Kennedy in the 'British Association Report for 1889,' p. 448, and 'Engineering,' Sept. 13, 1889.

COMBINATIONS OF APPARATUS FOR HOUSES AND LARGE BUILDINGS

81. It now remains for us to consider the combinations of apparatus that have been employed to provide for the efficient warming and ventilation of large rooms and buildings. The plans which have been adopted in different cases are extremely numerous and varied, and the accounts of the performances of the different apparatus are not easily compared. Sometimes

[1] In a paper in *La Lumière Electrique*, tome xi. 1884, p. 421, Prof. Lippmann calls special attention to the thermal economy of such an arrangement.

the ventilation depends entirely upon the draft of a large chimney-stack, the different rooms or parts of a large hall being connected with the stack by separate ducts; in others the large chimney is replaced by a fan; and either of these plans may be supplemented by open fires or separate ventilating flues, or the propulsion or plenum method may be employed as a substitute or an addition to the other forms of apparatus. The published descriptions or statistical information as to the action of the systems in actual use are seldom so arranged as to enable the reader to form a very precise opinion of the merits of the particular plan adopted. In warming and ventilation, perhaps more than any other subject, success or failure depends upon small details that may be passed over in description, and slight changes that seem at first sight unimportant may entirely change the aspect of the question, particularly when economy is an important element for consideration; for instance, a system which can be applied successfully to a high building of several stories may prove to be a failure when introduced into a building of the same cubic content distributed over a wide area in a single story.

How unsatisfactory the comparison may be in the question of cost may be gathered from the following extract from the very valuable report of Professor Carnelley upon the cost and efficiency of the heating and ventilation of schools.[1] He says (p. 45): 'In Nottingham (open fires) they burn nearly five times as much coal per head as in Dundee, and although coal is not much more than one-half the price, yet it costs them nearly three times as much per head of accommodation. The most extravagant "open fire" school in Dundee only burns one-half as much coal per head as the most careful "open fire" school in Nottingham. One open fire school in Dundee burns only 23 lb. per head, while one of the open fire schools in Leeds burns as much as 239 lb. per head! One of the "large hot pipe" schools in Dundee burns only 34 lb. of coal per head, while one of the "large hot pipe" schools in Nottingham burns 417 lb. per head. Either, then, they are inordinately extravagant in such towns as Leeds, Sheffield, Nottingham, &c. and are roasting the children, or we in Dundee are freezing them for the benefit of the ratepayers. It is to be noted that the same thing occurs, no matter what system of natural heating and ventilation is adopted. The result, therefore, cannot be due to any superior efficiency of our heating arrangements in Dundee.'

82. The report from which the above extract is quoted is a very complete arrangement of the results of an investigation of the ventilation and warming of 323 schools, of which 150 were personally visited. We give a few of the important conclusions from the summary on pp. 43–48.

First Cost of System of Warming and Ventilation

		Per head of accommodation	Per school of 1000 pupils
		s.	£
Natural ventilation	Open fires	4	200
	Small hot-water pipes (high pressure)	8	400
	Large hot-water pipes (low pressure)	10	500
Mechanical ventilation	As applied to schools suitably designed	17	850
	As applied to ordinary schools	20	1000

[1] Presented to the School Board of Dundee. Published by Winter, Duncan, & Co., Dundee.

Total Annual Cost

—	Cost per head of accommodation			Cost for a school to accommodate 1000 children		
	Interest on first cost	Annual cost	Total annual cost	Interest on first cost	Annual cost	Total annual cost
	d.	*d.*	*d.*	£	£ *s.* *d.*	£ *s.* *d.*
Ordinary systems .	$3\frac{1}{3}$	$2\frac{3}{4}$	6	14	11 9 2	25 9 2
Mechanical system .	8	$7\frac{1}{2}$	$15\frac{1}{2}$	34	31 5 0	65 5 0
Difference . .	5	$4\frac{3}{4}$	$9\frac{1}{2}$	20	19 15 10	39 5 10

Efficiency &c.

(*a*) *Radiation* v. *Conduction.*—With those systems, in which the rooms are heated by radiation rather than by conduction, the air is much more highly charged with micro-organisms than with those systems in which the rooms are heated more by conduction than by radiation.

(*b*) *Manchester Grates* v. *Ordinary Grates.*—As regards open fires, 'Manchester grates'[1] are much more effective in keeping the air of the rooms pure than ordinary grates.

(*c*) *Mechanical* v. *Ordinary Systems.*—Mechanical ventilation is undoubtedly far more effective in maintaining the purity and temperature of the air in schools than any of the ordinary methods usually adopted, and is hence more conducive to health and comfort.

(*d*) *Gas Engines and Water Engines.*—Gas engines are much cheaper and more effective than water engines for driving the fans.

(*e*) *Power of Gas Engine required.*—A two horse-power gas engine is amply sufficient for driving a 4 ft. Blackman or Aland fan (even one horse-power would probably be sufficient); while a one horse-power [engine] is sufficient for six of Cunningham's fans.

(*f*) *Blowing in* v. *Expanding the Air.*—The former is preferable.

(*g*) *Inlet Shafts.*—One large fresh-air inlet shaft is much better than several small ones, and the entrance to the shaft should be as free as possible.

(*h*) *Air Filters.*—Recommended. (See p. 51.)

(*i*) *Blackman's* v. *Cunningham's Fans.*—When *properly arranged*, a 4 ft. Blackman fan appears to be more effective and costs less both in fuel and in annual cost than the five or six Cunningham's fans usually employed to do the same work. Cunningham's fans are, however, more independent of the weather than either Blackman's or Aland's fans.

(*l*) *Time required to Change the Air of a School by Mechanical Ventilation.*—By mechanical ventilation the whole of the air in a school may be easily changed in less than fifteen minutes, and when the system is well arranged in less than ten minutes.

The statistics upon which these conclusions are based are given in the text and tables of the report. Some of the data must be modified when specially large or small schools are referred to. We quote also from the same report (p. 41) the following tabular statement of the advantages and disadvantages of the several systems :—

Open Fires

Advantages :

1. More cheerful.
2. First cost much less than hot pipe systems.
3. Keeps air fresher than hot pipes, owing to draught up chimney.
4. So far as the Dundee schools are concerned, the temperature in the open fire schools was higher than in those heated by hot pipes.
5. The rooms of these schools will probably need painting less frequently than those heated by other systems.

Disadvantages :

1. Greater labour in service.
2. Slightly greater annual cost than stoves, or steam-pipes, or large hot-water pipes.

[1] A form of ventilating open grate (see p. 124) delivering fresh air above the mantel-shelf.

3. Unequal distribution of heat.
4. Air more highly charged with micro-organisms.

STOVES

Advantages:

1. Smallest first cost.
2. Least annual cost.
3. Probably more effective heaters than open fires.

Disadvantages:

1. Greater labour in service.
2. Require more attention than open fires.
3. More liable to smoke than open fires.
4. More liable to get out of repair than open fires.
5. Not so cheerful as open fires.

HOT PIPES

Advantages:

1. Less labour in service than either open fires or stoves.
2. The class is not disturbed as in the case of the mending open fires and stoves.
3. More equal distribution of heat.
4. Air less charged with micro-organisms than when open fires are used.
5. On the whole the annual cost is probably *slightly* less than with open fires, but more than with stoves.

Disadvantages:

1. Not so cheerful as open fires.
2. First cost much more than in the case of open fires or stoves.
3. Air not so fresh as with open fires.

On hot-pipe schools.

1. Small high-pressure pipes are cheaper in first cost than large low-pressure pipes.
2. In those schools examined the air was better in rooms heated by small high-pressure pipes than in those heated by large low-pressure pipes.
3. It takes longer to get up the heat with large than with small pipes.
4. Small pipes are less obtrusive in the rooms.

MECHANICAL VENTILATION

Advantages:

1. Much greater purity as regards all the constituents.
2. Efficiency of ventilation much more independent of the weather; whereas with other systems the ventilation is worst when most needed.
3. The schools are warmer.
4. More equal distribution of heat and of fresh air.
5. Very effective in diminishing the number of micro-organisms, not only at the time the mechanical ventilation is in operation, but also for a long time after it has been stopped.
6. Reduces draughts to a minimum.

   In fact, the mechanical system heats and ventilates far better in every respect than any other system, and is therefore far more conducive to health and comfort, and to success in teaching and learning.

Disadvantages:

1. Greater first cost.
2. Greater annual cost (except in the case of very large schools).
3. Though in a town where several schools were heated and ventilated mechanically there would not need to be more than an ordinary caretaker in each of such schools, yet *one* of these should be a man who had some knowledge of gas engines &c. so that he could attend to any repairs which might be necessary. Such a man would require a somewhat higher wage than an ordinary caretaker. This, however, would amount to very little if distributed over a number of schools.

We are unable to present such statistical information in a condensed form for other kinds of buildings, and we do not think that much valuable information can be derived from a general account of the ventilation and warming of any particular building without the details upon which its success or failure depends. We therefore think it best to give here references to published

accounts of systems in actual use, so that the reader may be enabled to master the details for a similar case to the one with which he has to deal.

There is probably material enough existing in a published form for the compilation of a fairly complete report on the ventilation of *Barracks* and *Military Hospitals*. The information is to be found in the 'General Report of the Commission on the Means of Improving the Sanitary Condition of Barracks and Hospitals,' printed in the Parliamentary Papers for 1861, with its Appendix, issued in 1863; and in the 'Report of the Commission on Barracks and Hospital Improvement and on the Ventilation of Cavalry Stables' (1866); and further in the 'Report of the Commission on the Warming and Ventilation of Dwellings' (1857); and in Special Reports by F. de Chaumont, General Massy, and others, published in the 'Annual Reports of the Army Medical Department,' vols. vi. to x.

The ventilation of *Workhouses* and *Prisons* has also received considerable attention and is referred to in many Government publications; the best known of these is the 'Report of the Commission on the Cubic Space of Metropolitan Workhouses' (1867). An account of the arrangements at Pentonville Prison is given in the 'Prisons Report for 1847.'

Examples of the ventilation of *Prisons*, *Courthouses*, and other buildings, illustrated by clear diagrams, are given in R. Ritchie's 'Treatise on Ventilation' (1862). Descriptions are to be found in various books and periodicals of arrangements for warming and ventilation of all degrees of complexity, from the rudimentary system of Gurney's stoves in the crypt of St. Paul's Cathedral—which suffices for that building ('Mechanic's Magazine,' vol. lxix. 1858, p. 443), to the most elaborate and complicated schemes.

Taking some of the different departments in order:—The ventilation of *Dwelling-houses* is the subject of a Parliamentary Report already referred to. One of its recommendations is that in ordinary living-rooms ventilation should be provided for independently of the supply of air for the fire. Messrs. Drysdale and Hayward have, in their book on 'Health and Comfort in Housebuilding' (1872), given plans which they have found successful for supplying houses with suitably warmed air, and using the heat of the kitchen chimney as the agent for the general ventilation of the house. Arrangements are also described and figured in a book by Dr. Griscom, of New York (see also Spon's 'Dictionary of Engineering,' art. Ventilation).

An account of the ventilation of the *Lecture Theatre* of the Conservatoire des Arts et Métiers, by General Morin, is to be found in the 'Proceedings of the Institute of Mechanical Engineers' (1867). In this the fresh air is brought in at the ceiling and the foul air withdrawn through perforations in the risers of the seats. The elaborate arrangements for the ventilation of the *Théâtre Lyrique* are given in the same paper. General Morin also gives descriptions of the ventilation systems of many other buildings in the works of his already referred to in this article.

The ventilation of the *Houses of Parliament* has formed the subject of many inquiries and experiments; it has been treated in upwards of twenty reports to Parliament.[1] The original scheme proposed by Dr. D. B. Reid,[2] combining mechanical ventilation and heat-suction, seems to have proved unsatisfactory, partly in consequence of the interference with the original design, on account of misunderstandings with the architect. Subsequently,

[1] 1832, 1835, 1837, 1841 (four reports), 1843, 1846, 1847, 1848, 1852, 1854 (four reports), 1866, 1884, 1886 (three reports). The subject is still under discussion (see *Times*, July 25, 1891).

[2] *Report of the Committee on the Ventilation of the Houses of Parliament*, 1835; also Dr. Reid's *Illustrations of the Theory and Practice of Ventilation*, 1844.

Sir G. Gurney introduced the system of ventilation by steam jets; but in 1866, according to Dr. Percy, whose report, printed for the House of Commons (1866), gives a full description of the arrangements then and practically now in use, mechanical propulsion had been entirely abandoned, and the ventilation depends upon heat-suction alone, the air introduced being warmed by Gurney's 'Steam Batteries.' The suction seems, indeed, to have proved more than sufficient, for in 1884 the House was invaded by sewer gas from a main sewer passing under the building. An interesting account of the earlier history of tnis elaborate series of experiments in ventilation is given in Ritchie's book already referred to.

In *St. George's Hall*, Liverpool, Dr. Reid seems to have been able to carry out successfully his own ideas for a system of ventilation by mechanical means. A brief account of the arrangement is given in the 'Journal of the Society of Arts,' vol. ii. 1853–4, p. 757, and vol. iii. 1855, p. 379.

The ventilation of South Kensington Museum is dealt with in the Report of the Commission on that building (1869).

One of the most recent accounts of an attempt to carry out an elaborate system of ventilation and warming is given by Mr. W. W. Phipson, the engineer, in a paper in the 'Proceedings of the Institute of Civil Engineers,' vol. lv. 1879, p. 124, 'On the Heating and Ventilating Apparatus of Glasgow University:'—

In the year 1864, when the building of the new University of Glasgow was determined upon, a sub-committee of the professors, amongst whom were Sir William Thomson, Dr. Allen Thomson, Professor H. Blackburn, and the late Dr. W. J. M. Rankine, considered the general principles which should form the basis of the operation to secure for the new building the most efficient system of ventilation and warming. After a lengthened investigation they came to the following conclusions:—

1. That the foul air should be removed through outlets as near as possible to the place where it is produced, *e.g.* passages under desks or seats.
2. That the total area of the orifices of such outlets should be about $\frac{1}{5}$ square foot per sitting, or 28 square inches.
3. That the total area of the orifices of the inlets for fresh air should be about double the area of those of the outlets for foul air, or about $\frac{2}{5}$ square foot per sitting.
4. That the inlets for fresh air should be at a high level and distributed round the circumference of the rooms.
5. That fresh air should be supplied both hot and cold, and each classroom be provided with means for mixing it.
6. That the total supply of air to the classrooms should be $\frac{6}{10}$ cubic foot per sitting per second.
7. That the sectional area of the channels or conduits for carrying away foul air should be $\frac{1}{20}$ square foot per sitting.
8. That the final outlets of the foul air should be so placed that none of it should return to the building.
9. That the fresh air should be drawn from some place where the air is always pure.
10. That the fresh air should be forced in by one or any required number of suitable machines.
11. That the foul-air conduits should lead to chimneys in suitable positions provided with furnaces capable of being lighted, the area of the furnace grate being $\frac{15}{1000}$ square foot per sitting.
12. That the hot part of the fresh air should be heated by hot-water tubes, and that the most efficient position for such tubes was in the vertical passages in which the current of air ascends.

In working out these suggestions it was found that the allowance of $\frac{6}{10}$ cubic foot of fresh air per sitting per second for classrooms . . . was too much, and that the vertical air-shafts necessary to supply this large volume of air assumed such proportions that the walls would not admit of their construction.' It was therefore altered, but still the total volume passing through the apparatus was to be 1,800,000 cubic feet per hour. It appears also that

suggestion 5—about supplying cold fresh air as well as warm, with provision for mixing—was also abandoned.

In this paper and the discussions following it, which occupied two evenings, a good deal of light is thrown upon the whole question. Incidentally accounts are given of the ventilation of the *Free Trade Hall* and *Royal Exchange*, Manchester, by Mr. Constantine.

An abstract of the account of the arrangements for the *Vienna Opera House*, from the Proceedings of the 'Société des Ingénieurs-civils,' 1880, p. 431, is given in the 'Proc. Inst. C.E.' vol. lxiv. p. 450, and also of those of the *Bourse* in Berlin, *ibid.* vol. lxxi. p. 522. In this connexion we may also refer to a paper by the late Robert Briggs, 'On the Ventilation of Halls of Audience,' 'Trans. Amer. Soc. C.E.' vol. x. 1881, p. 53.

For the description of the ventilation of *Hospitals* the reader may be referred to the article on Ventilation in Spon's 'Dictionary of Engineering.' General Morin gives an account of the ventilation of Guy's Hospital (built by Rhode Hawkins) and of other hospitals in vol. i. of his 'Études sur la Ventilation,' p. 34, and of the Hôpital Lariboisière, in the same volume, p. 356, with full detail, and an investigation of the action. The system is based on the injection of air by fans. Dr. Arnott ventilated the hospital at York by pumps of his own design, worked by water power (see Arnott, 'On the Smokeless Fireplace' &c. or Ritchie's 'Treatise on Ventilation').

On the general principles of the ventilation of hospitals, there is a useful article in 'Fraser's Magazine' for November 1875.

Other departments of the subject are of a more technical nature. The ventilation of ships has received a good deal of attention, since Dr. Arnott made a report to the General Board of Health on the subject, which is contained in their reports on Quarantine, 1849–54. The modern development of this department for the cooling of ships &c. by mechanically cooled air is fully treated in a paper by J. J. Coleman on Air-refrigerating Machinery ('Proc. Inst. C.E.' vol. lxviii. p. 146) and the discussion upon it.

For information as to the ventilation of mines and tunnels, the technical journals must be referred to. For the former the ventilating fan seems to be coming more into use, and very large machinery is being employed for the purpose. Mechanical ventilators are now made to deliver 100,000 to 250,000 cubic feet of air per minute; the Guibal fan is made up to 50 feet in diameter, the Waddell fan up to 45 ft., while the quicker moving Schiele fan reaches 15 ft. This subject is considered in the work of M. Murgue, to which reference has already been made,[1] and is also discussed in the 'Proceedings of Inst. of Mech. Eng.' 1875, p. 317, by W. Daniel.

It appears from the 'Proceedings of the Institution of Civil Engineers' that the ventilation of underground railways sometimes receives a certain amount of attention. Exceptional cases of ventilation occasionally require treatment, which is noticed from time to time (see, for example, 'Electrician,' Feb. 22, 1889, p. 452).

The ventilation of sewers is a special department (see 'Annual Reports, Metropolitan Board of Works,' 1866–68–73).

A number of contrivances have been devised for the ventilation of railway carriages without draughts, but so far their success does not seem to be sufficiently conspicuous for their general adoption.

A general summary of the special points to be considered in the ventilation of buildings of special character is given by General Morin, 'Manuel,' § 163 *et seq.*

[1] See also *Reports on the Ventilation of Mines, Parliamentary Reports*, 1850; *Proc. Inst. Mech. Eng.* 1877, p. 92; *Proc. Inst. C.E.* xliv. p. 18, lxii. p. 396, xci. p. 541.

Taking all the points into consideration, it will be seen that although great progress has been made of late years towards the satisfactory solution of the problem of combined warming and ventilation, especially by the development of the mechanical system, we are still unable to regard the question as definitely settled. The most important point is that the prescribed amount of air for adequate ventilation (p. 116) is greater than can be supplied without very great extension of systems hitherto adopted. For crowded rooms in particular the areas of inlets and outlets would require to be enormous, and the maintenance of the flow would necessitate very extensive machinery. But, provided that those interested are willing to pay the price, the difficulties could no doubt be overcome. It is to be remarked that at present very little is accurately known, and very little account is taken of the local circulation of air in a large room, and so no advantage is consciously taken of this circulation in the provisions for ventilation. It would seem to be possible by a more accurate study of the distribution of the currents of air in a large room to remove the fouler portion of it more directly, and thus prevent its mixing with the purer portion, and so to reduce the amount of fresh air necessary.

Hitherto attention has been directed to this branch of the subject, mainly with the important object of avoiding draughts, and some measure of success has been attained; but when the necessary conditions for securing that object have been formulated and clearly understood, the next step may well be to direct the air supply with a view to its economy in comparison with its useful effect.

The economy of cost of heating, as well as the efficiency of ventilation, also depends largely upon this element, and for securing the same object more accurate knowledge of the magnitude of the air currents in ducts and the resistances of the ducts would render valuable aid, so that we look to the numerical expression of the details of circulations, both general and local, to provide the means of further progress.

METEOROLOGY

BY

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INTRODUCTORY

THIRTY years ago it would perhaps have been well to commence this section by demonstrating the relation between Meteorology and Public Health, but the necessity has rapidly diminished until now one sentence, just as a reminder, is all that can be required.

I have said thirty years, but might almost as well have said ninety, for as far back as 1796 Dr. William Heberden, F.R.S., submitted a paper to the Royal Society, 'Of the Influence of Cold on the Health of the Inhabitants of London,' and literature of that class has gradually increased until it fills many shelves. One cannot take up the Reports of the Registrar-Generals, of the Army Medical Department, or of the majority of the Medical Officers of Health, and of the Superintendents of our County Lunatic Asylums, without coming upon masses of meteorological data. Medical men, like Acland, Ballard, Mitchell, Moffat, Scoresby-Jackson, Shapter, Tripe, and scores of others, have discussed the relation of the two subjects. It is not for me to follow in their path, or review their work, but to explain as clearly as possible the construction and use of the various instruments employed by meteorologists, what are the good and the bad features of each, how they are to be placed, when they are to be read, how the observations are to be entered, and how they should be worked up and presented to the public.

ATMOSPHERIC PRESSURE

It is not very easy to explain why it is an almost invariable rule that when the numerous branches of meteorology have to be treated of, the barometer takes precedence over the thermometer. It is beyond the province of this section to consider the effect of variations of atmospheric pressure upon the human frame; [1] we have here to consider (1) how atmospheric pressure is measured, (2) what are the variations in its amount. Barometers may be roughly divided into two groups, those in which the pressure of the atmosphere is indicated by the length of the column of fluid (be it water, glycerine, or mercury) which it will support, or by the pressure which it exerts on the sides of a box which has been nearly exhausted of air, and then hermetically sealed. It is unnecessary here to deal with so elementary a matter as the principle of the barometer, but in explaining how to transport, erect, and read a thoroughly good mercurial barometer, most of the essential features will be incidentally mentioned. Nor is it necessary to spend time in specifying the faults of old patterns—a wheel barometer may be ornamental in a hall, may even sometimes induce one to take an umbrella, but is absolutely useless as a scientific instrument. For absolute accuracy there are two excellent patterns represented in figs. 53 and 54. Fig. 53 represents a standard barometer of the type introduced at the beginning of this century by a Frenchman, M. Fortin. The enlarged sketch, fig. 55, illustrates the special merit of this pattern. A moment's consideration will convince anyone that with a verti-

[1] Reference to *La Pression Barométrique*, by Paul Bert (Paris, 1858), may, however, be permitted.

cal tube and a cistern of mercury at the bottom, a fall of the barometric column must produce a rise in the cistern, and *vice versâ*. If then the scale of inches on the upper part of the instrument be laid off from a zero at any fixed point in the cistern, the barometer will read wrongly at every point but one; its motions will always be too small in the ratio which the area of the cistern bears to the area of the tube. In the Fortin barometer this error is removed by laying off the scale from the extremity of the ivory point, above A, fig. 55, and by, at each observation, so turning the screw at B that the mercury in the cistern is exactly in contact with that extremity of the ivory point. The other way of removing the difficulty is that shown in fig. 54, the so-called Kew pattern barometer, in which the cistern is closed (except as regards a wooden air inlet) and, its area having been accurately determined, the inches on the scale are not real inches, but inches of pressure, i.e. true inches so shortened as to compensate for the rise of the mercury in the cistern. It may be well to point out the merits and demerits of each of these patterns. The Fortin is the more difficult to make, and is therefore the more costly of the two, and the adjustment of the mercury to the ivory point requires care; on the other hand, it has two, if not more, great advantages; (1) the mercury can be screwed up so as to entirely fill the tube, and it then travels with less risk than if the tube be not full; (2) as long as the tube is not broken, and does not contain air, and there is mercury enough to fill the cistern up to the ivory point, the reading must be correct. The Kew pattern is lower in price and easier to observe, it is not so sensitive as a Fortin, because it is necessary to contract the tube, and if mercury escapes from the inner cistern the observer may continue to record the readings unconscious that they have thereby become worthless.

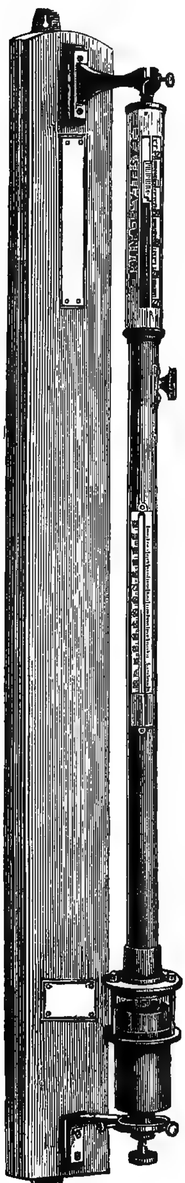


Fig. 53.

Fig. 54.

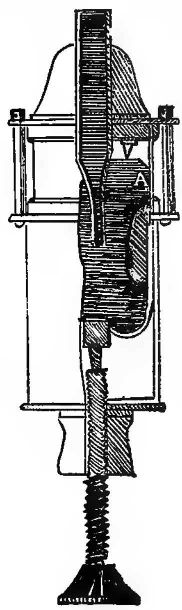


Fig. 55.

As regards the transport of barometers there is always great difficulty. The Fortin barometers should be so screwed up that the mercury rests steadily against the top of the tube, but this screwing up must not be done recklessly or the top of the tube may be knocked out by the mercury (for being a nearly perfect vacuum the mercury hits it like a pneumatic hammer), or the mercury may be squeezed through the pores of the leather bag, or even the bag itself burst. After being well screwed up, the barometer should be turned cistern uppermost, and if possible carried to its destination in that position. If this cannot be done it must be arranged to travel quite flat, and if practicable transversely to the direction of motion—e.g. in a gig, a barometer will travel better lying in the direction of the axle, than in that of the shafts. A broken barometer is not worth much more than a third of a sound one, hence it is true economy to spend a little extra for additional packing. The Kew pattern barometers are said to travel best lying flat.

On receipt of a barometer, the first thing is to select a good position. It should be one on which the sun rarely shines, and yet which has a good light, indoors, and where it is not likely to be interfered with. The 31-inch line should be at the level of the observer's eye; if the barometer be a Fortin, this should be rather higher, e.g. by using a stool, than for a Kew pattern, because with the Fortin it is also necessary that the observer see comfortably the ivory point in the cistern. On opening the case, the barometer itself will be found packed separately from the board on which it is to be suspended; this board should be firmly fixed in position, and then the barometer should be hung on it. Before actually fixing the barometer, it will be well to turn it cistern downwards, and slightly unscrew the cistern so as to let the mercury down an inch or two, then incline the barometer gently so that the mercury may run up to the top of the tube. It ought to elicit a sharp metallic click, but it may give only a dull thud; if on two or three trials it always gives a dull sound, it is because air has got into the tube and forms a cushion at the top. It is usually not difficult to remove the air in the following manner. Screw the mercury up until it is within about half an inch of the top of the tube, turn the barometer gently cistern uppermost, and tap the top of it on a thick rug, or on the toe of a boot for five minutes, then screw the mercury as tight as can be done without exerting strength enough to force any mercury through the wash-leather bag, turn the barometer cistern downwards, release the mercury and try whether the tap is not then clear and sharp. In all probability it will be, for the air has been gradually tapped out of the tube; if it is not gone, the process must be repeated either for a longer time, or with somewhat stronger taps.

At the bottom of the board will be found a ring with three adjusting screws. These should be nearly withdrawn, the barometer left free to assume a vertical position in the ring, and then the screws gradually turned in until they press upon it. Care must be taken that the screws are not turned after they are in contact with the barometer, or their pressure will prevent its remaining perpendicular, and then it will read too high.

Assuming the barometer free from air, and duly suspended, the next thing is to read it. In the Fortin pattern the first matter to attend to is the cistern: the mercury must be let down until its level just touches the tip of the ivory point; the best plan is to lower it rather too far, and then raise it slowly till it just touches.

Now we have to deal with the reading—by no means a complicated matter, but perhaps the most so of anything that a meteorological observer has to do. The first process is very easy: the observer has only to turn the screw of the vernier until he produces the state of things represented in

fig. 56—i.e. his eye, the front of the vernier, the summit of the mercurial column, and the back of the vernier all in one straight line. The second stage is to some persons a puzzle. The principle of the vernier—or nonius, as it used to be called—is the very simple one that if you put side by side two scales, on one of which a given length is divided into ten parts, and on the other into nine, the top and bottom lines will coincide, but the intermediate ones will each be one-tenth higher than those on the first scale; and so small excesses can be easily measured. Fig. 57 gives the vernier of a Fortin barometer in two positions: in A we see that the mercury is slightly above 29·6; this can be seen from the fixed scale; the line with the arrowhead is $29\frac{1}{2}$—i.e. 29·5; each of the long lines on the scale is ·1, and the short ones ·05; the mercury is not only above 29·5 but above 29·55 (the first short line above $29\frac{1}{2}$), and it is above the long line, and therefore above 29·6—it remains to see how much. In using the vernier the first thing is to decide which line on the movable scale is level with one on the fixed one; evidently it is the third line above the figure 1 on the movable scale. We have only to read that and add it to the 29·6 and all is finished. Now the first rule is that the figures on the movable scale are hundredths of an inch; therefore if the line marked 1 had been level with a line on the fixed scale one hundredth would have had to be added to 29·6—i.e.

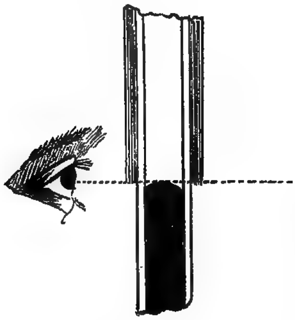
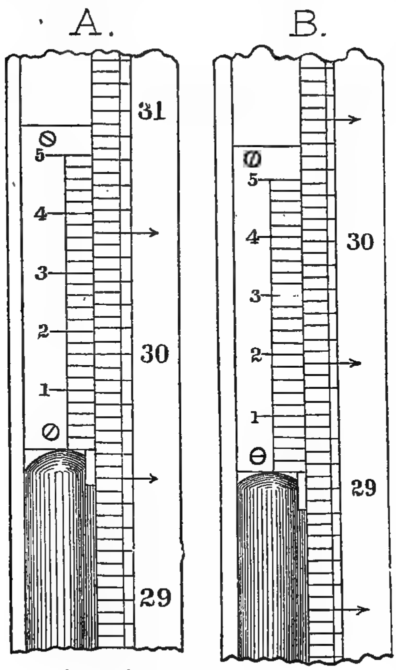


FIG. 56.

$$\begin{array}{r} 29{\cdot}60 \\ {\cdot}01 \\ \hline 29{\cdot}61 \end{array}$$

would have been the reading; but the line which cuts is three higher, and as each of these unnumbered lines represents $\frac{2}{1000}$ths, we have ·002 × 3 = ·006 above the ·01—i.e. ·016 to add to the 29·6, and so it comes out 29·616. To make the matter quite clear, example B is given. Here the mercury is above 29 inches, and slightly above 29·05 (the first short line); looking up the vernier we see that the line which cuts is the fourth, then ·002 × 4 = ·008, which, added to 29·05, makes 29·058 inches.



29·616. 29·058.

FIG. 57.

Assuming that the observer has thoroughly mastered the vernier, and the mode of setting it to the top of the column, we may now say a few words as to the routine of taking a reading with a Fortin: (1) read the attached thermometer to the nearest whole degree, and enter it; (2) lower the mercury in the cistern until it is quite clear of the ivory point, and then raise it gently until it *just* touches it; (3) bring the vernier to its true position; (4) read off and enter the reading; (5) it is well, but not indispensable, to lower the mercury in the cistern, so that it does

not remain in, or liable to, contact with the ivory point, as oxidation of the surface is hastened by such contact.

With a Kew pattern barometer the routine is the same except that (2) and (5) have not to be done.

There are three corrections which have to be applied to barometric readings; (1) index error, in which the effect of capillarity is now usually included; (2) temperature; (3) altitude.

Index error is usually very small, and is generally the same at all parts of the barometric scale. It is determined at the central observatory in each country and its amount entered on the certificate sent with the barometer.

Temperature.—If two barometers are in two adjoining rooms at the same level, but the one room is warm and the other cold, the barometers will differ, because in the warmer room the mercury has dilated and has therefore become of less specific gravity, so that in the warm room the barometer will read the higher. And the matter is further complicated by the fact that the inches on the brass scale also vary in length according to temperature, and are of their proper length only at 62° F. We do not employ barometers to tell us temperature but pressure, therefore it has long been agreed throughout all nations that barometer readings shall be reduced to what they would have been had both the mercury and the brass scale been at 32° F.

For barometers made (as all good ones are) with brass scales the corrections are as under :—

Temp.	27 inches	28 inches	29 inches	30 inches	31 inches
30	−·004	−·004	−·004	−·004	−·004
40	−·028	−·029	−·030	−·031	−·032
50	−·052	−·054	−·056	−·058	−·060
60	−·076	−·079	−·082	−·085	−·087
70	−·100	−·104	−·108	−·111	−·115
80	−·124	−·129	−·133	−·138	−·143
90	−·148	−·153	−·159	−·164	−·170
100	−·172	−·178	−·184	−·191	−·197

Detailed tables giving the values for each degree F. and for each half-inch of the barometer will be found in Guyot, Hazen, Marriott, Scott, and several other works.

ANEROIDS

Aneroids should never be relied upon for fixed stations; they are extremely useful instruments, and for some purposes invaluable; but after working well for periods, which may be a week, or may be twenty years, they will occasionally go hopelessly wrong. Checked, however, from time to time against a mercurial standard, an aneroid is, as a measurer of altitude, invaluable. The principle of the aneroid is very simple. Suppose two saucers made of corrugated iron, turned face to face, and soldered round the rim, and that by a small tube the air was exhausted from the interior, and the tube then closed, it is evident that the two sides of this corrugated flat box would be forced together by the pressure of the atmosphere, and that the compression would be equal to the equilibrium between the strength of the box and the pressure of the atmosphere; therefore, the greater the atmospheric pressure, the closer will the sides be squeezed together. This motion is, by suitable levers, made to turn the hand on the face of the aneroid. An aneroid should always be read in one position, not sometimes hanging on a nail and sometimes lying on a table.

RECORDING BAROMETER

There are many modes whereby barometers have been so arranged as to produce automatically a pencil, ink, or photographic record of the changes in the pressure of the atmosphere Most of these are too elaborate and costly for employment except in observatories, and therefore do not need mention here. But one very cheap and ingenious pattern has been brought out recently by MM. Richard Frères of Paris, to which a few lines may be devoted. Power is obtained from a series of aneroid vacuum boxes, the motion of which is multiplied by a long lever. The end of this lever carries a very small triangular box (the pen) filled with ink, which presses lightly against the paper-covered cylinder. Once a week a clock contained in this cylinder is wound up, and a new sheet of paper put on the cylinder, the pen on the extremity of the lever is provided with fresh ink (glycerine and a little aniline ink), and then, as the cylinder is rotated by the clock contained within

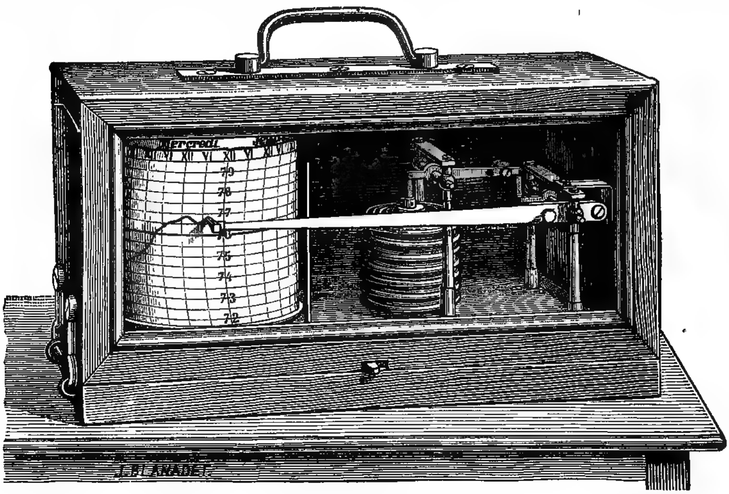


Fig. 58.

it, and the lever is higher or lower as the barometer is higher or lower, a very clear continuous ink record is produced. In fig. 58 the pen is at 7 P.M. on a Wednesday and the pressure is 768 millimetres or 30·28 inches. Papers can be had ruled to either metrical or English scale.

As has already been pointed out, aneroids such as this cannot be relied upon as certain to give absolute accuracy, but checked from time to time against a mercurial standard they are most useful, and the diagrams are very interesting.

MEASUREMENT OF HEIGHTS

It would be beyond our limits to give elaborate rules and formulæ for the barometric measurement of altitudes, but it may be convenient to give sufficient simple ones to enable any one to form (e.g.) a rough idea as to whether a spring in one valley could be utilised in another. It is immaterial whether an aneroid or a mercurial barometer be used; in either case the barometer should be read three times. Suppose that it is required to

know the height of A above B. Read the barometer at A, take it to B, read it there, go back to A and read it the third time. Suppose the readings to be

$$\begin{array}{lll} & \text{in.} & \text{in.} \\ \text{A (1st time)} & 30{\cdot}10 & \text{B } 29{\cdot}90 \\ \text{A (2nd time)} & 30{\cdot}14 & \end{array}$$

$$\begin{array}{lr} \text{Then take the mean at A} = & 30{\cdot}12 \\ \text{,, ,, reading at B} = & \underline{29{\cdot}90} \\ \text{Difference} & {\cdot}22 \text{ inch.} \end{array}$$

The simplest rule is, move the decimal two places to the right and multiply the difference by 9, thus:

$$\begin{array}{r} {\cdot}22 \\ \underline{9} \\ 198 = \text{difference in feet.} \end{array}$$

A closer approach to the truth can be obtained with great ease by means of the annexed diagram,[1] and attending to the following rules—(1) Find the mean pressure at the two stations; in the above example $\frac{30{\cdot}12+29{\cdot}90}{2}=30{\cdot}01$. (2) Find (or estimate) the mean temperature; suppose it to be 70°. (3) Look in the diagram where the line for 30 inches crosses that for 70°, and read off the slanting value for that point; it will be seen to be the dotted line for $9\frac{1}{2}$ or 9·5 *that* is the multiplier to be used, and so we get

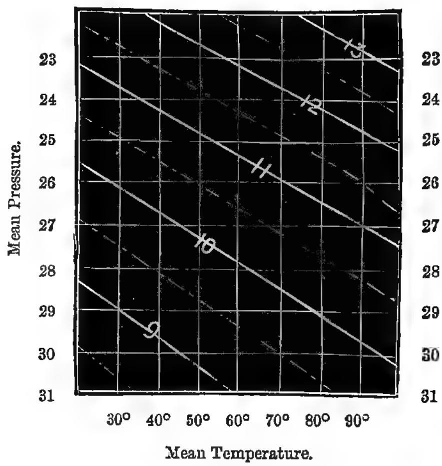


FIG. 59.

$$\begin{array}{r} {\cdot}22 \\ \underline{9{\cdot}5} \\ 110 \\ \underline{198} \\ 209{\cdot}0 \end{array}$$

, or 209 ft. instead of 198 ft. as by the simpler rule.

Reference to the diagram will show that 9 would have been absolutely right at a temperature of 45°, and that the multiplier rises with the temperature.

REDUCTION OF BAROMETER TO SEA-LEVEL

For sanitary purposes we advise that this be never done; it is obviously of no medical or sanitary importance to a resident at Buxton to know what the pressure of the barometer would be if he dug a well 1,000 feet deep and went to the bottom of it. Reduction to sea-level is a necessity to the meteorologist, but not to the climatologist or the student of hygiene. If either of them wishes to apply the correction accurately, he can consult Guyot's, Marriott's, or Scott's tables; if he wishes to know it approximately, he can for small elevations add one-tenth of an inch for each hundred feet.

[1] From *Pocket Meteorological Tables.* By G. J. Symons.

DAILY RANGE OF THE BAROMETER

In most parts of the world the barometer has daily a double tide, rising to maxima about 10 A.M. and 10 P.M. and falling to minima about 4 A.M. and 4 P.M., but the amount of these fluctuations is small, and I am not aware that it has ever been suggested that they in any way affect public or individual health.

EXTREMES OF PRESSURE

At the level of the sea the average pressure may be put at 30 inches, and the variations at from 27 inches as the minimum to 31 inches as the maximum. When I mention that in his memorable Wolverhampton ascent Mr. Glaisher went so high that the pressure fell to less than 8 inches, and that in the caisson for the great Forth Bridge the men worked in a chamber so far under water that the barometer stood at 72 inches, it will be seen how great is the range which the human frame can sustain and how insignificant as compared with it are the atmospheric fluctuations of 4 inches—4 against 64.

TEMPERATURE

A few prefatory remarks on thermometers in general will probably not be superfluous, as few persons know the reasons for the very different patterns of thermometer, or how to select that best adapted for the object which they have in view. It is very difficult to compress within any reasonable limit all that ought to be said upon the subject, and therefore my remarks must of necessity be somewhat curt. Thermometers may be classified as Ordinary, Registering, and Recording.

Ordinary Thermometers

In early days these consisted of glass tubes filled with alcohol or mercury, tied with wire to slabs of wood or of ivory, on which the divisions were marked; the bulbs were large and the glass was often very thick. Alcohol (and other liquids) proving inferior to mercury, the latter is now in good instruments alone employed (except, as will be noted presently, under the head of registering thermometers); the bulbs are thin and much smaller, because opticians have learned how to make the bore of the tubes oval, and to mount them with the broad side of the tube foremost. This gives an appearance of breadth to the column, and therefore makes it easily seen, while the smallness of the bore enables the size of the bulb to be reduced, and the smaller the bulb the more sensitive the thermometer. If a large bulb be indispensable it is best made as a cylinder, not as a sphere, because a cylinder exposes more surface, and therefore takes up the temperature more rapidly. Another great improvement, which we believe was due to Messrs. Negretti and Zambra of London, is the working into the tube of a layer of opal glass. This (which is called enamelling) white background throws up the thread of mercury, and has done more than anything else to enable thermometers to be made with small, and therefore, very sensitive bulbs. Again, now, all good thermometers have the scale etched on the tube, which (1) lasts as long as the thermometer itself, instead of perishing as did the old wood and ivory ones; (2) which cannot slip about as did the old frames; (3) which avoids parallax by bringing the division as close as possible to the mercurial column. For ordinary house or

hospital use, glass or porcelain slabs to carry and protect the thermometer are the cleanest and most permanent; glass is better than porcelain because sometimes moisture penetrates the glaze of the latter, and, freezing underneath, splits off flakes of the porcelain, disfiguring, if not ruining, the instrument. This evil seems, however, to be decreasing, owing probably to improved manufacture. There is a notable difference between British and Continental makers as regards the mounting of thermometers, and probably (as is frequently the case) something between the extremes is best. Continental makers of high-class thermometers seem to consider that the tube should have no mounting whatever; they form a loop in the glass of the end of the stem and consider the instrument complete. An English maker, on the contrary, nearly buries his tube in a wood, glass, or zinc mounting. Each has a good feature, and each a bad one. The Continental plan leaves the thermometer free to assume the temperature of air, or of any body in which it is immersed, but it leaves the tube very fragile. The English plan protects the tube from breakage, but not infrequently so surrounds the bulb as to cause it to show a temperature intermediate between that of the slab to which it is attached and that of the air or other surrounding medium.

Thermometers can now be had of almost any degree of minuteness or delicacy which can be imagined. I have seen some with their tiny bulbs inside the green shoots of growing plants; others with cylindrical bulbs coiled flat like a snake, with the scale rising perpendicularly from the centre, the coiled bulb not so large as a shilling, being for taking local temperatures, and the scale, perhaps $1\frac{1}{2}$ inch long, for reading them off. And the accuracy of thermometers is now very remarkable, provided that nothing unreasonable be expected of the makers. Some persons imagine that an accurate thermometer can be made of any required pattern as quickly as a coat. This is impossible, and a thermometer made in a hurry generally proves a bad one. Until within a very few years any mercurial thermometer on which the divisions were etched within a year of the bulb being blown and filled, was sure to become from a quarter to half a degree too high within the following six months, wherefore the best makers kept large stocks of filled, but ungraduated tubes, and rarely put the divisions on until they were two or three years old. Some years since Mr. Denton, a skilled thermometer maker, discovered that, by a process of slow annealing in hot oil, this change could be effected in weeks instead of years, and now, if the matter be insisted upon, and a reasonable price paid, thermometers can be bought which have what is called a constant zero—i.e. which will not read higher by age. Now it will be seen why thermometers should not be made hurriedly, and that if a purchaser insists upon one being made and delivered within a week, the maker will probably so divide it that it shall read 0·2° or 0·3° too low when supplied, because he knows that eventually it will rise not only so as to become correct, but possibly 0·2° or 0·3° too high.

The only ordinary thermometer required for climatological purposes is the one mounted along with another to form an hygrometer. I shall, therefore defer its description until I write upon hygrometry.

Registering Thermometers

There are two terms often confused and misused by amateurs—self-registering and self-recording; the word 'self' being in both cases redundant and misleading. The proper application is registering to anything which moves an index which can be subsequently examined: a gas meter is a self-registering apparatus; on the contrary, any instrument which by pen, pencil,

photography, or otherwise makes a continuous trace upon paper, &c., produces a record and is recording.

It would be quite out of place to describe any patterns of registering thermometer, except those in general use; this will exclude probably a hundred patterns, and leave scarcely half a dozen—the survival of the fittest.

The oldest, invented about 1780 by James Six of Canterbury (not Colchester, as is often stated), is not now used for climatological purposes, but is very popular as a window thermometer, and is convenient as a check on the warming of public buildings, hospital wards, &c.; it is also much used for taking the temperature of the sea, and can do so even under several miles of water, and when the pressure is two or more tons to the square inch. Fig. 60 represents the instrument as fitted for a window. The bulb of the thermometer is the long cylinder in the middle, which, as well as the upper part of the 'cold' tube, is filled with alcohol; below this the tube is filled with mercury, which passes round the bend at the bottom and part way up the 'heat' tube. Above this the space in that tube is also filled with alcohol, except that in the upper part of the chamber at the top there is confined some air which was sealed in at so low a temperature that at any ordinary temperature it exerts a pressure upon the alcohol in the 'heat' tube, and then, through the mercury, upon the alcohol in the 'cold' tube. The effect, or supposed effect, of this is to keep the two liquids in their place, and to prevent air bubbles escaping from the alcohol and deranging the instrument. These are its drawbacks, and they make it a very bad traveller. A Six's thermometer, if well made and once safely in position, is the handiest self-registering thermometer in use, but it should be moved as little as possible and always carried vertically. The difficulty arising from motion will soon become evident. The indexes consist of three parts (and are not always made of the same shape or materials): (*a*) the steel needle; this is essential but it is sometimes bare, sometimes enclosed in a little glass tube; (*b*) knobs of glass at each end of the index, the lower one to be driven up by the mercury; (*c*) springs to hold the index in position and prevent its falling; these are sometimes bristles, sometimes bent threads of glass. The action of the thermometer is simple and very ingenious. Suppose that the instrument has just been read; to set it ready for the next observation take a horse-shoe magnet and place it successively at the side of each needle and draw the indexes gently down until they rest upon the mercury; the lower knob of each will then read alike and will show the temperature at that instant. Having done so, suppose that the temperature rises, the alcohol in the bulb will expand, it will pass the index in the 'cold' leg, and push down the mercury, but that will compel the mercury to rise in the 'heat' leg, and to drive up the index in it until the temperature ceases to rise, when the index will be left behind and the maximum temperature will be registered by the position of the bottom of that index. Just the reverse will happen on a fall of temperature, for then the spirit in the bulb will contract, the pressure in the chamber at the top of the 'heat' leg will force the mercury down in it and up in the 'cold' one, and it will push that index upwards as long as the temperature continues to fall. It is obvious from the above that the temperature scales must read downwards in the 'cold' and upwards in the 'heat' leg, and that in each leg the bottom of the index shows respec-

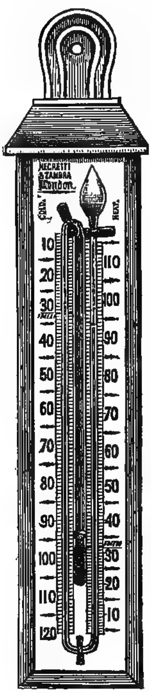


FIG. 60.

tively the lowest and the highest temperature reached since the instrument was last set. It is evident that a thermometer of this kind placed inside a fixed, locked, wire cage gives evidence of the variations in temperature between two consecutive visits of the superior officer.

Before leaving this pattern it is necessary to mention one peculiar error to which this thermometer is liable. Sometimes alcohol will ooze round by the side of the mercury, and so pass from the 'cold' to the 'heat' leg. This is doubly bad (*a*) because, inasmuch as the scales run in opposite directions, it can only be detected by comparison with another thermometer, and (*b*) because no one but an optician can rectify the evil.

RUTHERFORD'S MINIMUM

All the world over this very simple pattern of thermometer holds the first place as a minimum thermometer; not that it is perfect—it has several faults, but because no other has been able to displace it. It was invented nearly a century since and described in 1794 in the 'Ed. Phil. Trans.' Its action, as will be seen from fig. 61, is very simple. The bulb and part of the stem are filled with alcohol in which a glass index is placed: when the temperature falls, the cohesion of the end of the alcohol is sufficient to draw the index back with it towards the bulb; but when the temperature rises again, the alcohol passes the index and leaves the extremity furthest from the bulb at the lowest temperature reached. The end of the

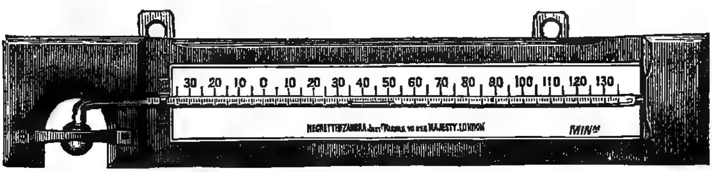


FIG. 61.

column furthest from the bulb should always agree within about half a degree with that of an accurate mercurial thermometer hung by its side. I make this reservation as to 0°·5 because spirit thermometers, being sluggish, differ from mercurial ones when rapid changes are in progress. This thermometer does not require a magnet to set it; its usual position is nearly horizontal; if anything, the bulb end slightly lower than the other. To set it, unhang it and raise the bulb, the index will then of its own weight slide down to the end of the column. Two faults occur with this thermometer: sometimes, but rarely, bubbles of air appear in the column and fix the index; more frequently error arises from the distillation of some of the alcohol, and its condensation at the top of the tube. This is generally visible without difficulty, but is not obvious, because if the alcohol in the stem be, as is usual, coloured, that which condenses at the top is frequently quite colourless. At one time opticians frequently buried this portion of the tube under the mounting, but that practice has fortunately been abandoned. Both these faults are usually easily cured by the observers themselves, and both by the same process. Hold the thermometer firmly near the bulb, and bulb downwards; then swing it rapidly with the right hand, taking care, of course, to hit nothing; the centrifugal force will usually cause a broken column to unite, and will throw any alcohol from the top of the tube. After so swinging the thermometer, it should be stood bulb downwards for an hour so as to drain, and it will be well afterwards to compare it with a mercurial one to see that all is correct. The index will very probably be thrown into the

bulb by this swinging, but a very little gentle coaxing will bring it out again. Sometimes, if the tube be very fine and the amount of condensed spirit very small, it has not momentum enough to move from the top; it can then be displaced only by evaporation, and a match or a small spirit lamp should be applied to the tube where the condensed spirit is lodged. Of course care must be taken not to apply heat so suddenly as to crack the tube.

PHILLIPS'S MAXIMUM THERMOMETER

This thermometer, invented by Professor J. Phillips, F.R.S., as early as 1832, and described by him in the 'Report of the British Association' for that year, was remarkably slow in becoming known. How it was, and why it was, that twenty years after its invention the Royal Observatory was still employing the very bad maximum invented by Rutherford, is one of the facts which it is difficult to explain. It was probably partly Professor Phillips's well-known modesty, and partly that no optician had a pecuniary interest in pushing it. Possibly the very slight use made of the invention in this country led to its being unknown to, or ignored by, M. Walferdin, who described an identical arrangement to the Académie des Sciences, April 24, 1854, as his own. To the same cause must probably be attributed the following curiously incorrect statement by M. Renou:[1]—'Depuis quelques années les Anglais ont adopté ce thermomètre qu'ils appellent

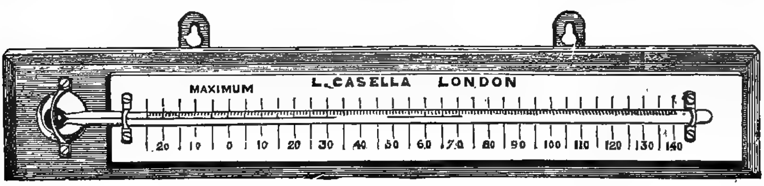


FIG. 62.

thermomètre à maximum de Phillips, mais à tort, l'invention appartient bien positivement à M. Walferdin.' Reference to the 'British Association Report' settles the question of priority by twenty-two years in favour of Phillips, though very likely the invention by M. Walferdin was genuine. On the Continent this pattern is generally described not by either name but as 'thermomètre à bulle d'air.' Its construction is shown by fig. 62; it is very simple and easily understood. In the manufacture a very small bubble of air is introduced into the tube, separating 10° or 15° at the extremity from the remainder of the column. In the pattern represented by fig. 62, and which is that used for meteorological purposes, this detached portion will be seen to be many degrees away from the top of the column, but that is merely for the convenience of illustrating the principle. Assume that the thermometer is found as per fig. 62, it then shows that since the instrument was last set, the temperature had at some time reached 70°·8. To set the thermometer it should be taken off the hooks and the bulb end lowered until the detached portion runs back and nearly joins the top of the column (with some thermometers even a slight shake may be necessary), then re-hang it nearly horizontal, bulb end slightly lowest; it will then show the existing temperature, and when any increase occurs the detached portion will be pushed along, its extremity furthest from the bulb marking the highest temperature reached; if the temperature fall, this detached portion is left behind and thus registers the maximum.

[1] *Annuaire Soc. Mét. de France*, t. xxiv. p. 61.

If the index-column be short, this form of thermometer can be used in any position, vertical or horizontal, bulb up or bulb down, and I have myself used it in a well 1,000 feet deep, where it had to bear the jolts of raising and lowering by a windlass; the only difference is, that with such a short index a sharp swing is necessary to reset it.

As thermometers on this principle can be made with extremely fine bores it has been very largely adopted for clinical thermometers; in fact, it was used in the very first made for Dr. Aitken by Mr. Casella, and since that time probably 100,000 have been made upon that model.

NEGRETTI AND ZAMBRA'S MAXIMUM

While Phillips's maximum was lying dormant, if not forgotten, the Great Exhibition of 1851 was opened, and the jury who had to deal with meteorological instruments, having nothing before them except specimens of Six's and of Rutherford's thermometers, and, strangely enough, apparently not knowing of Phillips's maximum, pointed out that a trustworthy maximum was much wanted. Messrs. Negretti and Zambra were determined to meet this want, and in little more than a year brought out their excellent patent maximum which is shown in fig. 63. Like Phillips's, it is (for meteorological purposes) used in a nearly horizontal position—the bulb slightly lower than the top. Its construction is as follows:—First an ordinary thermometer

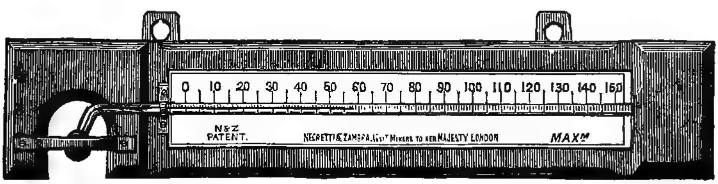


FIG. 63.

tube (rather large) is prepared; then a thread of glass about one-fourth of an inch long is dropped down to near the bulb end, and the stem at that point and the contained fibre are heated to softness and slightly bent. This fixes the fibre and forms an obstruction in the tube, which tube is subsequently filled with mercury as an ordinary thermometer. When in use, if the temperature rises, the mercury in the bulb expands and forces its way past the obstruction; but if the temperature falls, the molecular attraction of the mercury is insufficient to induce the column to pass the obstruction, and therefore the full length remains in the tube, and the extremity shows the highest temperature reached. The thermometer is reset by lowering the bulb end and, if necessary, giving the thermometer a swing, bulb downwards.

IMMISCH'S THERMOMETERS

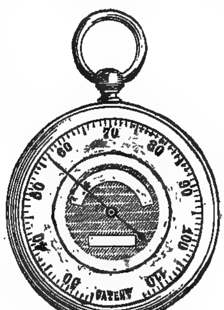


FIG. 64.

These are extremely small, accurate, and handy thermometers which, as fig. 64 shows, are quite unlike an ordinary thermometer. They owe their indication to the expansion of a liquid in a small tube, bent nearly to a circle, which tends to straighten with increase of heat; this motion is, by very fine mechanism, made to cause the hand to travel over the dial. It is quite usual for these little thermometers to be true to less than 0°·1 F. Some are graduated for

ordinary use, some for the limited range required for clinical purposes. Mr. Immisch has recently added an arrangement which makes them virtually registering.

RICHARD'S RECORDING THERMOMETER

Until lately the cost of recording thermometers was so great (70*l.* or 80*l.*) as to prevent their adoption at any but richly endowed observatories; but within the last few years MM. Richard Frères of Paris have perfected the pattern shown in fig. 65, and sell them at so low a price as to render the instrument generally accessible; it therefore claims a few words here. The bulb, like Immisch's, is a curved, flattened tube filled with a liquid, but as it has more work to do it is enormously larger. The changes in the curvature of the tube cause the long lever to rise with increase of temperature and to fall with decrease. This marks on a cylinder on exactly the same system as the barograph already described. When duly wound up and started it

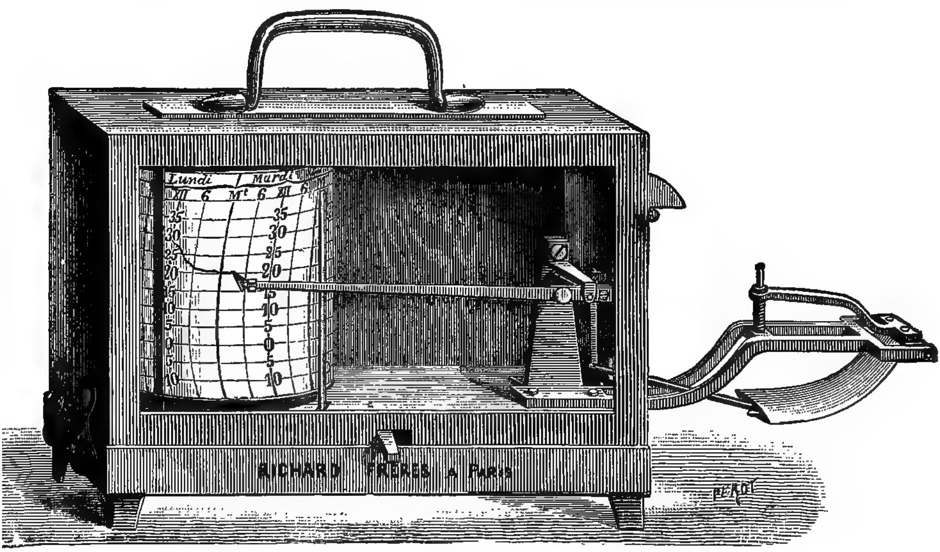


FIG. 65.

can be locked up and left untouched until the corresponding hour in the following week, when a record, true, probably, to 0°·5 F., will be found for every instant during the week. As the curvature of the tube or the strength of the spring will sometimes alter, the reading of an accurate mercurial thermometer should be noted when a new sheet is put on, so that, if necessary, the position of the lever may be adjusted to correspond with it.

HYGROMETRY

This branch of meteorology is not in a satisfactory state. Quite two hundred forms of hygrometer have been devised, but, except in rare cases and for experimental purposes, only two survive, viz. the dry and wet bulb (sometimes erroneously called Mason's) hygrometer, and Saussure's hair hygrometer. The dry and wet bulb is almost the only form used in the British Isles and in our Colonies, and it is the more usual on the Continent, but as frosts are more intense at Continental stations than at British ones, and the

wet bulb thermometer requires great care and attention in time of frost, it is usual on the Continent to have also a Saussure hair hygrometer and to fall back upon it in frosty weather.

Dry and Wet Bulb

The general form of the dry and wet bulb hygrometer is shown in fig. 66. It is an easy instrument to read, and, provided that it be supplied with rain or distilled water and with clean muslin and wick, requires no attention except in frosty weather; then it has to be visited about half an hour before the regular time of observation, and the muslin brushed over with a camel-hair brush dipped in cold water; this will freeze before the time of the regular observation, and the reading of the ice-covered bulb will give as correct an indication of the humidity of the air as does the bulb when wet.

Perhaps some very elementary remarks upon the use of this instrument may be excused, for, common as it is, there are many who do not know the principle upon which it is based, nor, *e.g.*, what is the temperature of evaporation, or what its relation to the temperature of the dew point. It would be out of place to give here a treatise on hygrometry; we give only some fragments.

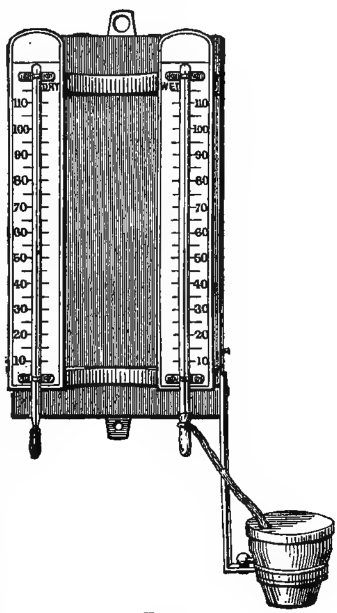


Fig. 66.

The dry and wet bulb thermometer indicate the amount of moisture present in the air by the difference between the reading of the two thermometers: the dry bulb gives the temperature of the air, the wet bulb gives a temperature lower than that of the air, in proportion to the rapidity with which the water is removed from the wet bulb by evaporation. To take a homely illustration, when one's head is too hot, one applies eau de Cologne, because the rapid evaporation of the spirit will quickly cool the skin; so does the water cool the wet bulb thermometer. Moreover, the drier the air, the faster does the evaporation proceed, and, therefore, the greater the cooling; hence, roughly, the greater the depression of the wet bulb below the dry, the drier the air—we have said *roughly*, because the value of a depression of (say) 6° is much greater at low than at high temperatures.

For anything like intelligent use of a dry and wet bulb thermometer a set of tables is indispensable; those generally used in this country were compiled many years since by Mr. J. Glaisher, F.R.S., but analogous ones have since been prepared in many countries.

It remains for us to point out the meaning of the term 'dew-point temperature:' it is that temperature at which the air will deposit the moisture contained in it. This can be ascertained directly by Dines's hygrometer (see p. 166) or by calculation from the reading of the dry and wet bulb thermometer. *Very roughly* it may be said to be about as much below the wet bulb reading as the wet bulb itself is below the dry.

In a perfectly saturated atmosphere the two thermometers should read alike. Sometimes the wet bulb will read a few tenths higher than the dry

bulb; this not infrequently leads hasty persons to the conclusion that one of the thermometers must be wrong. This does not follow: first, because when the air is saturated the dry bulb is almost always coated with a thin film of water, is, in fact, a better wet bulb than the one covered with muslin; and, secondly, because the proper wet bulb is by its covering of muslin protected from radiation, and so kept slightly warmer than the air.

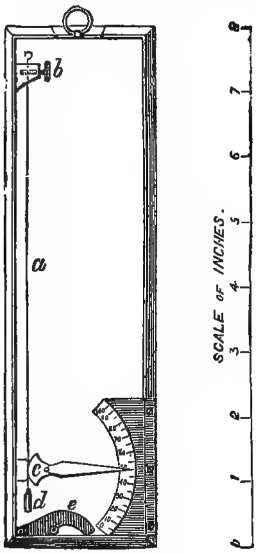


Fig. 67.

The depression of the wet bulb below the dry bulb, which, as just explained, in a wet fog is *nil*, may, in rare cases, even in England, exceed 20°; but the average difference ranges from 1° or 2° in winter to 6° or 8° in summer.

Saussure's Hygrometer

One form of Saussure's hygrometer is shown in fig. 67. It is not an independent instrument, but has to be set to correspond with the value as computed from a dry and wet bulb thermometer. It depends upon the fact that a human hair elongates by moisture and contracts by dryness. A hair (a) is therefore (after proper treatment as to grease, &c.) fastened at one end (b), while the other has a slight weight (d) attached to keep it stretched, and is fastened to a lever so that its movements may be magnified and easily read upon the scale. The total motive power of the hair being very small, the friction of the axle becomes a serious element, and I have seen a form of the instrument in which there was no friction. The hair was fixed at its upper extremity, the tension was provided by a small weight tied to the bottom of the hair, which hung in the centre of a pierced tube, the lower part of which was of ground glass with divisions etched upon it; the reading was by a microscope so arranged that it and the bottom of the weight could be brought exactly opposite the scale and the length then read off.

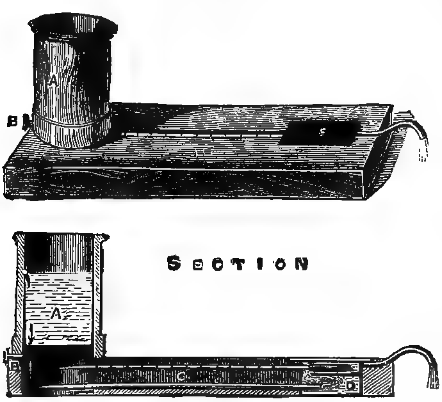


Fig. 68.

Dines's Hygrometer

This is the simplest form of condensation hygrometer, of which the earlier types were the hygrometers of Daniell, Regnault, Alluard, and others. Dines's is distinguished from all the others in that it only requires ether when the dew point is at or below 32°; at all higher temperatures cold water is alone required. One form of it, which well illustrates its principle, is shown in perspective and section in fig. 68. The vessel A is filled with cold water (ice being added if required), which passes over the thermometer bulb, and at the same time against the under surface of the very thin sheet of glass at E. The observer watches for the deposition of dew on the glass, and the thermometer at that instant gives, without any calculation, the dew-point temperature.

RAINFALL

This subject has on account of its great engineering importance received much attention, and there are now few countries in the world without special organisations for its registration. As the natural result thereof, considerable approach has been made towards uniformity in the pattern of rain gauge and in the mode of registration. It used (fifty years since) to be not unusual to put rain gauges on roofs (I suppose that they might be the nearer to where the rain came from), but long before that it had been shown (but forgotten) that gauges on elevated buildings collect much less than those near the ground.[1] In the British Isles, in India, Ceylon, Canada, and in nearly all our Colonies, the gauges are one foot above ground. On the continent of Europe, in Algeria, Java, and Sumatra, they are generally from three to five feet above the ground, and therefore record about three per cent. less than they would do if at one foot. In the United States, owing to the Signal Office stations being mostly in the heart of cities, a great many of the rain gauges are understood to be on house tops. No satisfactory discussion of American rainfall can be based on such observations.

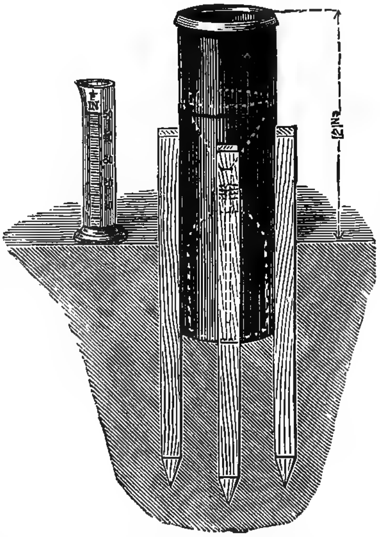


FIG. 69.

The pattern of gauge generally used in this country is shown in fig. 69; this represents one five inches in diameter, but there are also many eight-inch ones at work, and those established in France by the Association Française of about eight and a half inches diameter are very similar in pattern. The vertical portion of the funnel, i.e. that above the cone, is known as a Snowdon rim (from having in England been adopted first for gauges intended for use near Snowdon), and is intended to secure the accurate measurement of slight falls of snow. Having entered the funnel, the rain passes down through a tube, made long and narrow to check evaporation, into the bottle, where it remains until measurement. If the fall be exceptionally great, or if a sudden frost sets in, freezes the water, and cracks the bottle, the record is not spoiled, for the water is saved by the can, and may be measured almost as well as if nothing had happened. The measuring jar is divided proportionally to the area of the gauge, the diameter of which should always be an exact dimension, 5·00 inches or 8·00 inches, as it is then easy, if the original measuring jar is broken, to obtain a new one precisely adapted to the funnel. The principle of graduation is so obvious as scarcely to need mention. Take a 5-inch gauge; if the diameter be 5 inches the area is 19·64 inches, therefore a rainfall of an inch, i.e. 1 inch deep over the whole of a parish or town, would in this rain gauge deposit 19·64 cubic inches, or 4958 grains of water. It is found in practice most convenient to make the jar hold half an inch. Therefore 2479 grains are poured in and the jar is marked with a line representing 0·50 inch or $\frac{1}{2}$ inch; subdivisions are similarly marked, and so finally

[1] This deficiency has been proved to be due to the wind blowing the rain over, and out of, the funnels of gauges in exposed positions.

the jar has fifty divisions, one for each $\frac{1}{100}$th of an inch, and is figured at ·10, ·20, ·30, ·40, and ·50. As regards the general manner of observing and recording rainfall, it seems best to reprint *in extenso* the rules drawn up for the use of British observers.

SUGGESTIONS FOR SECURING UNIFORMITY OF PRACTICE AMONG RAINFALL OBSERVERS

1. *Site.*—A rain gauge should not be set on a roof, a slope, or a terrace, but on a level piece of ground, at a distance from shrubs, trees, walls, and buildings—at the very least as many feet from their base as they are in height. Tall-growing flowers, vegetables, and bushes must be kept away from the gauge. If a thoroughly clear site cannot be obtained, shelter is most endurable from NW., N., and E., less so from S., S.E., and W., and not at all from S.W. or N.E.

2. *Old Gauges.*—Old-established gauges should not be moved, nor their registration discontinued until, at least, two years after a new one has been in operation, otherwise the continuity of the register will be irreparably destroyed. Both the old and the new ones must be registered at the same time, and the results recorded for comparison.

3. *Level and Fixing.*—The funnel of a rain gauge must be set quite level, and so firmly fixed that it will remain so in spite of any gale of wind or ordinary circumstance. Its correctness in this respect should be tested from time to time.

4. *Height.*—The funnels of gauges newly placed should be 1 ft. above grass. Information respecting height above sea-level may be obtained from the Editor of 'British Rainfall.'

5. *Rust.*—If the funnel of a japanned gauge becomes so oxidised as to retain the rain in its pores, or threatens to become rusty, it should have a coat of gas tar, or japan black, or a fresh funnel of zinc or copper should be provided.

6. *Float Gauges.*—If the measuring rod is detached from the float, it should never be left in the gauge. If it is attached to the float, it should be pegged or tied down, and only allowed to rise to its proper position at the time of reading. To allow for the weight of the float and rod, these gauges are generally so constructed as to show 0 only when a small amount of water is left in them. Care must always be taken to set the rod to the zero or 0.

7. *Can and Bottle Gauges.*—The measuring glass should always be held upright, or placed on a level slab; the reading is to be taken midway between the two apparent surfaces of the water.

8. *Time of Reading.*—9 A.M. daily; if taken only monthly, then 9 A.M. on the 1st.

9. *Date of Entry.*—The amount measured at 9 A.M. on any day is to be set against the previous one; because the amount registered at 9 A.M. of, say, the 17th contains the fall during 15 hours of the 16th, and only 9 hours of the 17th.

10. *Mode of Entry.*—If less than one-tenth (·10) has fallen, the cypher must *always* be prefixed; thus, if the measure is full up to the seventh line, it must be entered as ·07, that is, no inches, no tenths, and seven hundredths. There must always be two figures to the right of the decimal point. Even in the case of one-tenth of an inch (usually written ·1) a cypher must be added, making it ·10. Neglect of this rule causes much inconvenience. All columns should be cast *twice*—once up and once down, so as to avoid the same error being made twice. Never copy a total, always cast the column afresh. When there is no rain, a line should be drawn rather than cyphers inserted.

11. *Caution.*—The amount should always be written down before the water is thrown away.

12. *Small Quantities.*—The unit of measurement being ·01, observers whose gauges are sufficiently delicate to show less than that, are, if the amount is under ·005, to throw it away; if it is ·005 to ·010 inclusive, they are to enter it as ·01.

13. *Absence.*—Every observer should train some one as an assistant; but where this is not possible, instructions should be given that the gauge be emptied at 9 A.M. on the 1st of the month, and the water bottled, labelled, and tightly corked, to await the observer's return.

14. *Heavy Rains.*—When very heavy rains occur, it is desirable to measure immediately on their termination, and it will be found a safe plan after measuring to return the water to the gauge, so that the morning registration will not be interfered with. Of course if there is the slightest doubt as to the gauge holding all that falls, it must be emptied, the amount being *previously* written down and added to the subsequent measurement.

15. *Snow.*—In snow three methods may be adopted—it is well to try them all. (1) Melt what is caught in the funnel by adding to the snow a previously ascertained quantity of warm water, and then, deducting this quantity from the total measurement, enter the residue as rain. (2) Select a place where the snow has not drifted, invert the

funnel, and, turning it round, lift and melt what is enclosed. (3) Measure with a rule the average depth of snow, and take one-twelfth as the equivalent of water. This being a very rough method, is not to be adopted if it can be avoided. Some observers use in snowy weather a cylinder of the same diameter as the rain gauge, and of considerable depth. If the wind is rough, all the snow is blown out of a flat-funnelled rain gauge. Snowdon pattern gauges are much the best.

16. *Overflow.*—Not a year passes in which some gauges are not allowed to overflow; it is therefore necessary to call attention to the fact that there does not seem to be any part of the British Isles where 4 inches may not fall in 24 hours. It is not desirable to purchase any gauge of which the capacity is less than 6 inches.

17. *Second Gauges.*—It is desirable that observers should have two gauges, and that one of them should be capable of holding 8 inches of rain. One of the gauges should be registered daily, the other weekly or monthly as preferred, but always on the 1st of each month. By this means a thorough check is kept on accidental errors in the entries, which is not the case if *both* are read daily. Observers having two gauges and recording both daily, should keep the records distinct, and forward a copy of each. Never take a mean of two.

18. *Dew and Fog.*—Small amounts of water are at times deposited in rain gauges by fog and dew; they should be added to the amount of rainfall, because (1) they 'tend to water the earth and nourish the streams;' and not for that reason only, but (2) because in many cases the rain gauges can only be visited monthly, and it would then obviously be impossible to separate the yield of snow, rain, &c.; therefore, for the sake of uniformity, all must be taken together, and as, except by watching all night, it is never possible to be certain that small amounts are wholly dew, it is best to count all entries of ·01 in or upwards as days with rain.

19. *Doubtful Entries.*—Whenever there is the least doubt respecting the accuracy of any observation, the entry should be marked with a ?, and the reason stated for its being placed there.

20. *Breakage.*—The Editor has no desire to supply rain gauges or glasses, or in any way to undertake, or interfere with, that which is the business of opticians; but the continuity and permanent accuracy of the records of his correspondents is to him of such importance, that he deems it advisable to announce that any assistance in his power is always at their service.

21. *Leakage.*—Observers should test their gauges occasionally to see that the amount collected is neither increased nor decreased by leakage.

THERMOMETER SCREENS

During the last half century it has been increasingly recognised that it is useless to have accurate thermometers, and to aim at comparing climates, unless the thermometers are placed under similar conditions at the two or more localities which it is desired to compare. The first, in order of date, of the special screens designed for this purpose was erected about 1841 at the Royal Observatory, Greenwich; it is generally known as

Glaisher's Stand

It consists of one horizontal, one vertical, and two sloping boards. It is made so that it can be turned round, and thus the face on which the thermometers hang kept away from the sun, and with three thicknesses of wood and two layers of air between the sun's rays and the thermometers. This pattern is, in order to secure continuity of record, still retained at Greenwich and at some other stations. It was formerly general at the stations of the British Meteorological Society and at those established by the Royal Engineers, but is now rare, as, though a great advance upon anything up to the date of its construction, it is found to have the following disadvantages. (*a*) It does not prevent rain and snow falling on the thermometers, (*b*) the turning two or three times a day is troublesome, and if forgotten the thermometers may be exposed to the direct rays of the sun,

(c) the thermometers are warmed by radiation from the ground and neighbouring objects, unless surrounded by quite a large space of grass.

Stevenson's Screen

I cannot trace the precise history of this pattern. In an address to the Meteorological Society of Scotland, delivered January 14, 1857, by Dr. Stark, F.R.S.E., the secretary, there is the following paragraph :—

The Committee have had long and earnest discussions relative to the mode of exposing the instruments to the weather. It is quite apparent that, if we wish comparable results, the instruments must be similarly exposed; and the Committee have, meanwhile, recommended that the instruments should be exposed in a box, with double open louvre-boarded sides, 1½ inch being between the sides, with a sloping roof to carry off the rain, and raised 4 feet from the ground. To suit instruments of all sizes it is convenient to have the inner box about 18 inches in internal width by 14 inches in depth and 8 inches in breadth; and it may either be fixed in an open spot over grass, or, if a low window with a northern exposure can be had, it may be fixed in front of it, and the side next the window may be made single, and to open downwards, so that, when opened, the door would rest on the window sill.

It is a pity that this description was not accompanied by an engraving; and it is to be noted that Mr. Thomas Stevenson, C.E., who eventually brought out the Stevenson Screen, was a member of the committee in whose name Dr. Stark was speaking.

Three years later (March 29, 1860) the Council state that boxes have been erected at most of the Society's stations, but that they are not uniform, that there is considerable difference of opinion as to the best form, that experiments were to be instituted by the secretary to ascertain the best pattern, and that the Council hoped to publish the results in the next report. I cannot trace any record of these experiments, or of their result. In fact, the subject seems to have slumbered until June 1864, when in a paper in the Journal of the Scottish Meteorological Society Mr. Stevenson gave a description and sketch of the stand almost precisely as it is still made. Fig. 70 gives a representation of it, which leaves only one point needing mention—namely, that the venetians are double, falling both inside and outside, and with half an inch between them at their highest points. They are on one frame cut herring-bone-wise, which not only saves cost, but also bulk, and the hollow between the two sets causes nearly all rain to drop through instead of running up one slope and down the other, and being thence blown on to the thermometers. This is not a perfect stand suitable for all climates; no such stand has been devised, but the Stevenson certainly seems well adapted for this country, and is rapidly supplanting all others.

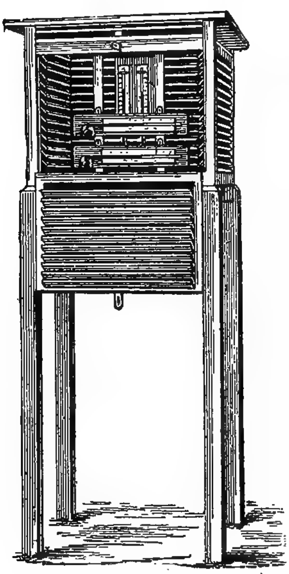


Fig. 70.

Montsouris Thermometer Stand

Fig. 71 represents the pattern of stand generally used in France. The southern sun is shut off by the double roof A, morning and evening sun by the wings B C. As already stated, thermometers in France are not mounted

on slabs as in England, but the maximum and minimum can be seen hanging at *a* and *b*, while other instruments are placed at *d* and *e*. It will be noticed that the stand is approached by several steps, rendered necessary by the fact that in that country the thermometers are usually 8 or 9 feet above the ground, instead of 4 feet as in England.

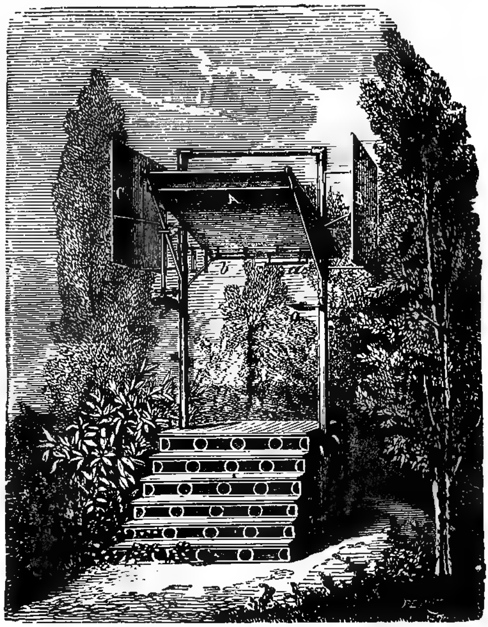


Fig. 71.

I have dealt rather fully with the previous instruments because they are the fundamental ones for all climatic work, and the very fact that I have done so will enable me to dispose of some of the other instruments very briefly.

SUNSHINE

Although means of recording approximately the duration of sunshine were devised more than thirty years since, the instrument has only lately been brought into a compact and handy form, therefore the general use of sunshine recorders is much more recent. At present (owing chiefly, it is stated, to the cost of procuring and grinding good glass spheres) sunshine recorders are rather expensive,

Fig. 72.

but, partly perhaps from their novelty, their adoption is becoming frequent. There are many patterns; one available for the tropics, or indeed for any

latitude, is shown in fig. 72, p. 171. The principle is very simple; whenever the sun shines brightly, its rays, focussed by the sphere, fall on a strip of cardboard and burn a hole; as the world turns round, if the sun continue to shine, the hole is elongated and becomes a slit, which if no clouds intervene will continue till nearly sunset. The length charred is therefore a distinct measure of the duration of sunshine.

Another arrangement for obtaining analogous records, is by placing sensitised photographic paper in the box shown in fig. 73. The sun shines in through a tiny hole, and while shining acts on the paper, the photographic trace on which is fixed by washing in clean water, and the record can then be read off.[1]

To distinguish between the two methods it has been proposed to call the photographic one sun*light* records, and the burnt ones sun*shine* records.

Solar Radiation

To determine the heating power of the sun's rays appears at first sight

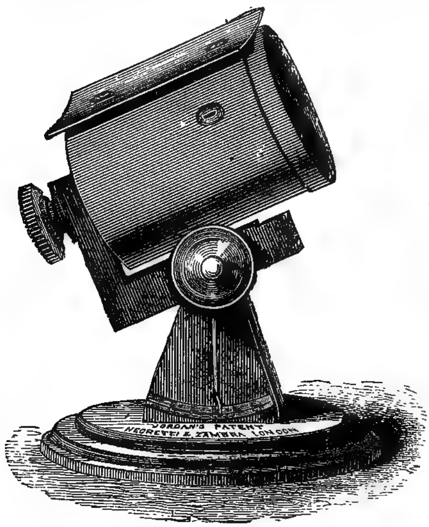


Fig. 73.

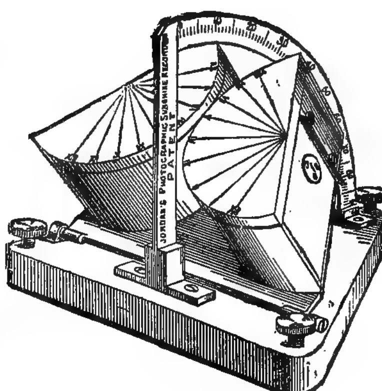


Fig. 74.

extremely easy; put a maximum thermometer in the sunshine and you have it at once. Oh no, very far from it. If your thermometer be clean and bright, the mercury in it will act as a spherical mirror, and instead of absorbing the sun's heat rays will reflect them. Then make the bulb of black glass; still the vitreous surface will act as a partial reflector. Then coat it with lampblack; still two evils—(*a*) the first shower will wash it off; (*b*) unless part of the stem be blackened as well as the bulb, the cold stem will chill the bulb. Blacken both thermometer and part of stem, and put it inside a glass jacket, pump out as much air as you can, and having done so seal the tube hermetically. Those are the reasons for, and the stages by which the black bulb in fig. 75 was arrived at. But we are still far from obtaining the true heat of the sun's rays. Putting the thermometer into the vacuum jacket not only protects it from rain but largely from another very important influence—wind. Evidently the reading of a naked black bulb thermometer is intermediate between that produced by the sun and that of

[1] Fig. 74 represents a form of this intended for any latitude.

the air in contact with it; the stronger the wind the more rapidly will fresh particles of air impinge upon the thermometer bulb and the lower will it read. Even the jacket does not wholly abolish this evil, because the wind cools the glass jacket, and the jacket and the bulb interchange heat by radiation, and therefore part of the influence of wind remains. Then there is another difficulty. Suppose that on two consecutive days the black bulb in vacuo read 128°, but that the temperature of the air on the first day was 70°, on the second 80°; one sees at once that the sun's rays must have been more powerful on the first day than on the second, because on the first they raised the black bulb 58° above the air temperature, and on the second only 48°. At present the best plan is to have two thermometers as nearly identical as possible, except that the bulb and part of the stem of one is coated with lamp-black, and the other is left bright; both are in vacuum jackets, both on one post, pointed in the same direction (preferably to S.E.) and both four feet above grass, and to consider as the amount of solar radiation the excess (in degrees) of the black bulb above the bright bulb thermometer.

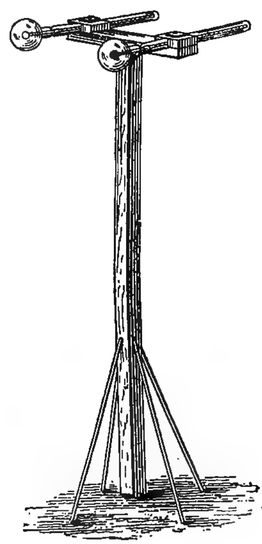


Fig. 75.

Terrestrial Radiation

Everybody does not know, what is however quite true, that, as a rule, a grass plot is considerably colder than a flower bed or a gravel walk, and that all are considerably colder than the air three or four feet above them. This cooling is due to the rapidity with which (when there are no clouds) grass radiates heat into space. The amount of terrestrial radiation is therefore

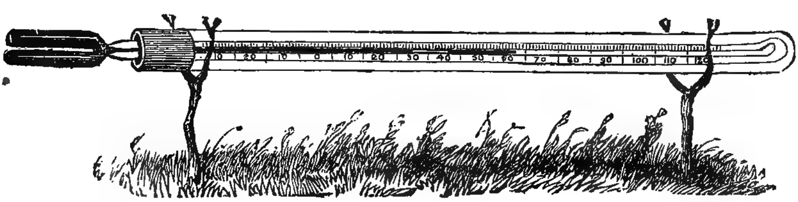


Fig. 76.

nearly proportional to the absence of cloud. It is determined by placing Casella's modification of Rutherford's minimum thermometer (fig. 76) on a grass plot, and noting the difference between its reading and that of the minimum in the Stevenson screen.

Earth Temperature

The broad general features of earth temperature are, that at depths of a few inches the temperature does not differ very widely from that of the air, but as the depth increases the amplitude of the daily and seasonal changes decreases, and the latter also suffer retardation, so that at two or three feet the minimum, instead of occurring in the beginning of January, falls late in February, and the maximum, instead of July 16, falls late in August, and the maximum is so much lower and the minimum so much higher that the range there is less than half what it is at the surface.

At ten feet the retardation amounts to nearly three months, and the range is reduced to about 8°·0, and at 25 feet the range is only about 3°, and the minimum is retarded until June and the maximum till December, so that probably at about 35 feet, where the range is reduced to 1°, the maximum occurs at the date of greatest winter cold and the minimum at that of maximum summer heat.

The observation of earth temperature was formerly difficult and the thermometers themselves were extremely delicate and costly, as the old plan was to have a long and fine bore tube with a large bulb, and bury all but the upper portion in a pit, leaving the scale at the top visible, so that the thermometer could be read. Anyone can realise the difficulty and danger of breakage attending the construction, transport, and fixing of a thermometer 25 feet long, with a heavy bulb at the end of it. The modern plan (fig. 77) is to close the bottom of a piece of stout iron tube, to drive it or bury it in the ground to the desired depth, and to lower into it, by a chain, a slow-action thermometer (i.e. one with a large bulb and coated with non-conducting material so that its indications will not change while being raised), which is hauled up by the chain whenever a reading has to be taken. In short ones, like fig. 77, the thermometer is let into a stick attached to the covering cap. Another immense advantage of the new plan is that the thermometer can be verified whenever desired. The old thermometers, once placed, could not be raised, and their errors were never known.

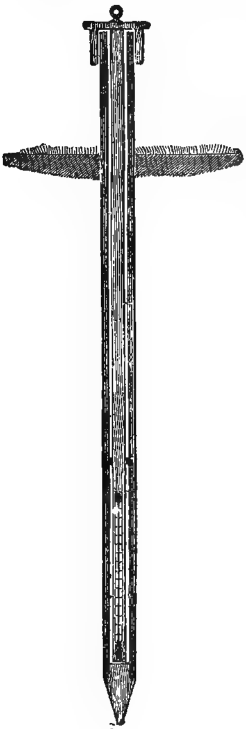


FIG. 77.

WIND

DIRECTION

As regards direction it is questionable whether for sanitary and hygienic purposes any apparatus is needed; there is no vane so sensitive and true as the smoke from a chimney, and when an observer has once fixed accurately the precise position of his meridian, nothing else is required but care and common sense.

It may be well to mention the very easiest way of finding the meridian, at any place where true *local time* is known. The sun is due south at noon or within a minute thereof during the following periods:

April 11th to 18th.
June 9th to 18th.
August 28th to September 3rd.
December 22nd to 25th.

If, therefore, a pole be erected vertically as tested by a plumb line, the shadow from it will fall true N.W. at 9 A.M., N. at noon, and N.E. at 3 P.M. The (in all other respects) very advantageous spread of uniform time, *e.g.* Greenwich time, throughout England and Wales, and Paris time throughout France, has led to local time being lost sight of. It can always be obtained from uniform time by correcting for longitude as in the following case.

What is the local time at Bath when it is 9 A.M. Greenwich time?

Reference to any map will show that Bath is 2° 20′ W. of Greenwich. Degrees and seconds of longitude multiplied by 4 give minutes and seconds of time.

Then

$$\begin{array}{r} 2^\circ\ 20' \\ 4 \\ \hline 9\text{m. } 20\text{s.}; \end{array}$$

and as Bath is W. of Greenwich, local time there is earlier than at Greenwich, therefore at Bath 9.0 Greenwich time corresponds to 8h. 50m. 40s. local time. In other words, on the dates above set out, the sun at Bath is due south at 0h. 9m. 20s. Greenwich time.

It may be thought that it is easier to lay down the true cardinal points by the Pole star, which can be seen any starlight night, and which is never very far away from true N., but I do not think so. Others may say why not do it by a compass, allowing for variation. If the observer is sure that he knows the variation, if he duly allows for it and does not apply it with the wrong sign, well and good; but these hints are not written for experts (had they been, I should have suggested the method of equal altitudes), but merely to point out to beginners the path which contains the fewest pitfalls.

The motion of clouds is by no means to be ignored, but it will be found that only the very lowest can be taken as indicating surface wind. The motion of high clouds is, however, interesting, and at times indicates that to which the surface wind will gradually shift.

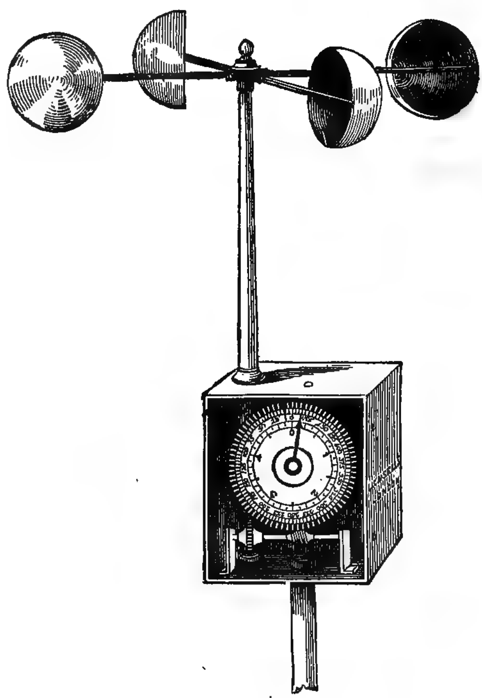


FIG. 78.

FORCE OR VELOCITY OF WIND

This is a rather difficult subject, and one at present in a state of confusion. It is generally stated that what is known as the Robinson's cup anemometer was first made known in 1850 by a paper published in the *Trans. Roy. Irish Acad.* in 1855; but this is not correct, as the *Report of the British Association*, 1846, part 2, p. 111, shows that (1) the original suggestion was not Robinson's, but Edgeworth's; and (2) that the instrument was at work in 1846, four years before the above paper was written. That, however, is merely the correction of a little bit of false history.

Robinson's anemometers, being those by far most generally used, claim a few words of description and comment. Fig. 78 shows the simplest form. From whatever direction the wind may blow it will meet the hollow face of two cups and the rounded face of two others; it will exert more force upon the former than upon the latter, and therefore it will cause the whole four to rotate; and the stronger the wind the faster will be the rotation. On the

shaft which carries these four arms there is an endless screw which works in teeth cut in the circumference of the dials, and so (by arrangements, into the detail of which I need not enter) the hands indicate on the dial the number of miles of wind which have passed since the previous reading. The fundamental principle upon which these instruments are graduated, is that the cups move with one-third of the velocity of the wind—i.e. that if the centres of the cups are 1·12 feet apart each revolution would correspond to 3·52 feet of motion, and (*if the factor be really* 3) to 10·56 feet of wind, then ($10·56 \times 500 = 5280$ ft.=1 mile) 500 rotations would indicate the passage of one mile of wind.

I said that this subject is in a state of confusion; it is so for this reason, that it has been proved that the factor is not 3, but something between 2 and 3, probably about $2\frac{1}{2}$. This may appear a small matter, but it is not; its effect is that all wind velocities are reported greater than they really are—a wind of 50 miles an hour is called one of 60 miles an hour, and so on. Besides this fundamental error there are others, such as the retardation due to friction, which varies with the velocity; at very low velocities, two or three miles an hour, the friction is so nearly equal to the wind force that many anemometers stand still; but, on the other hand, when the wind gets to, say, fifty miles an hour and the cups have to make seven complete rotations in each second of time, friction becomes relatively unimportant. And it is not merely legitimate friction from which anemometers suffer. I have seen the anemometer on an observatory (where there was no lack of money) coated with a sticky compound of soot and oil quite half an inch thick—that was not fair play. I have photographs of the anemometers at several mountain observatories quite unrecognisable under their mantle of hoar frost. Evidently the indications of instruments in such circumstances are not worth the paper upon which they are recorded—still less are they worth reducing and publishing.

Another great difficulty with anemometers is that of finding a suitable position for them. No one can be found to approve the existing practice of meteorologists with respect to anemometry, and yet hardly any one has the courage to insist on a new departure. Almost universally in this country and on the Continent the anemometer is mounted on the highest part of the observatory, with no regard to what height it may be above the ground, nor to the shape of the building. Now it is well known and obvious that air currents are retarded by friction, and that therefore the greater the height above the ground the greater the freedom with which the wind moves, and therefore the greater its velocity. And it is equally obvious that if a wind current meets a building, it cannot go through it, and must therefore pass it either laterally or over the top; hence it is that the wind at some feet above the top of the building is generally greater than that of the true air current at that level.

The foregoing remarks, while probably useful historically, are also designed to act as warnings to those who may think that if they go to a good optician for a Robinson's anemometer and then fix it in position, they will *ex necessitate* have an accurate record of the velocity of the wind. Besides the false factor (I believe no one has yet abandoned the 3 to 1), they must see that it is in a thoroughly open position, not less than ten feet above ground, with no buildings near it, and that it is kept scrupulously clean and frequently supplied with fresh oil.

Occasionally the wind's force is reported in lbs. per square foot: this is sometimes obtained from a pressure anemometer (of which the best known is Osler's) and sometimes computed from the recorded velocity on the assump-

tion that the square root of 200 times the pressure in pounds equals the velocity in miles per hour—i.e.

$$\sqrt{200\,P} = V, \text{ or conversely, } V^2 \times \cdot 005 = P.$$

But this factor of 200 is as doubtful as that of 3 for the ratio of Robinson's cups.

There are many tables given for roughly estimating the force of the wind, but they differ greatly. I think that the following, given by Mr. R. H. Scott, F.R.S., in his *Instructions*, is the best, but possibly the velocities may be considered too great when the 3 is finally replaced by 2·5 or whatever is the best value. The 90 miles might then come down to 75.

Beaufort Scale	Description	Velocity in miles per hour
0	Calm	3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

AMOUNT OF CLOUD

It has not yet become the practice to record this except by estimation, but it is surprising with what accuracy these estimates are made. As a rule observers ignore from the horizon up to about 20°, and confine their estimate to the zenith and 70° from it towards the horizon. This space is supposed to be divided into 10 parts; if there is not a trace of cloud, the amount is 0; if there are equal amounts of blue sky and of cloud, 5; if entirely overcast, 10. It is not so easy to determine the amount after dark, but an observer soon learns the constellations, and uses the absent stars as evidence of present cloud.

FORMS OF CLOUD

This is one of the branches of meteorology in a transitional state. At the beginning of this century Luke Howard, F.R.S., who has been well called the Father of English meteorology, wrote an essay upon the subject, proposed a nomenclature and submitted a series of descriptions of clouds, which, in spite of the enormous advances in other branches of meteorology, still hold the first rank. Even photography has not yet helped very much, because it of course has the difficulty of producing similar effects by white clouds and their blue background. Much has been, and is being, done, especially in Sweden, France, and England, and various alterations of Howard's classification have been suggested, but not one of the new proposals has met with general adoption, and therefore I quote only Howard's, and in his own words.

CIRRUS (*mares' tails*—the loftiest cloud; Mr. Glaisher, F.R.S., when five or six miles high, in Coxwell's balloon, saw cirri far above him).—Parallel, flexuous, or diverging fibres, extensible by increase in any or in all directions.

CIRRO-CUMULUS (*mackerel sky*).—Small, well-defined roundish masses in close horizontal arrangement or contact.

CIRRO-STRATUS.—Horizontal or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward or undulated; separate or in groups consisting of small clouds having these characters.

The foregoing are the clouds chiefly prevalent at great heights; the following are usually lower.

STRATUS (*ground-fog*).—A widely extended continuous horizontal sheet, increasing from below upward.

CUMULUS (*mountain-like clouds, often with a silver lining*). Convex or conical heaps, increasing upward from a horizontal base.

CUMULO-STRATUS.—The cirro-stratus blended with the cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide-spread structure to its base.

NIMBUS.—The rain cloud. A cloud or system of clouds from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally and from beneath.

MISCELLANEOUS PHENOMENA

Under this head I purpose giving merely a few hints respecting phenomena, which mostly can be observed without instruments, or at any rate without those usually regarded as meteorological ones.

SNOW.—In sharp frost the patterns of snow crystals are frequently of exquisite beauty. The best way to see them is to expose slabs of coloured glass; when these become cold, and the air is below 32°, crystals will remain unchanged for hours, and if care be taken not to breathe upon them, they can be examined and drawn with perfect ease. Directly the temperature rises all their beauty vanishes. Their size varies, but is generally from $\frac{1}{10}$th to $\frac{3}{10}$ths of an inch in diameter.

HAIL.—This varies much; probably according to the conditions of its formation; sometimes it is so soft as to resemble a soft snowball; sometimes it is very hard crystalline ice; sometimes the stones are formed of alternate layers of clear and opaque ice. When the hail is very soft, it is frequently pyramidal in shape, and not infrequently radial (like iron pyrites) in its texture and cauliflower-like at its base, giving in short the idea of a ball which had split up into segments. There was a wonderful fall of this kind in and near London at 3.15 P.M., March 8, 1857. Mr. Glaisher observed and photographed some of the stones at Greenwich, and I examined those which fell near Buckingham Palace; at these widely-separated places the fall was very similar, the stones (only happily they were very soft) being about one inch long and $\frac{3}{4}$ inch in diameter at their base. Howard reports a somewhat similar fall, but of stones or rather snow pyramids of little more than half the above dimensions. Pyramidal soft hail is common, but I have never seen or heard of any case like that of 1857. When exceptional hailstorms occur, prompt attention should be given to weighing *accurately* some of the largest stones that can be found. Accurate weight is the most essential feature, next to that shape and size, then structure, whether clear or opaque, number of alternate layers, &c. Then evidence should be collected illustrative of the force of fall; this is partly afforded by the greatest thickness of glass broken, by the indentation of zinc or corrugated iron roofing, by damage to plants, poultry, &c. It used to be stated that hail never fell at night; this is not now asserted, but it is so much more rare by night than by day that nocturnal hail-falls should always be fully reported.

THUNDERSTORMS.—Full instructions upon observing thunderstorms and lightning having been issued by the Royal Meteorological Society, it is not necessary to dwell at length upon the subject. Briefly it comes to this—note the time of first thunder, most thunder, and last thunder, and similarly of lightning—notice the shortest time interval, i.e. the interval between seeing the lightning and hearing the thunder belonging to that flash—roughly, each five seconds' interval corresponds to a distance of a mile. If any object is struck, collect as full details as practicable. As regards human beings killed by lightning there is much to be learned, for the marks on, and changes in, the body vary immensely—whether they depend on the intensity of the shock, on the state of the skin as to perspiration (I believe that not infrequently vapour saves a man's life—it acts as a conductor—is so electrified that it strips the man of his clothes, but it keeps the charge outside his body, and so saves his life). This question of perspiration is very important, because at present there is no evidence whether the vapour is converted into high-pressure steam by heat, or whether the water particles are repelled by becoming similarly electrified. I think that the latter is the more probable, but the observed fact is that persons whose feet are hot generally have their boots burst open and flung from their feet, while they personally suffer little hurt. Evidence as to the thickest piece of metal fused by lightning is very much wanted.

OZONE.—Thirty years ago no meteorological station was considered to be properly equipped without a box of ozone test papers—strips of foolscap paper dipped in iodide of potassium and starch. During the cholera epidemics of 1849 and 1854, great attention was given to the subject, and I personally think that it is a pity that the observations were given up. It is true that the papers were not uniform, that distinguished chemists scorned the plan, and that Dr. Fox wrote a large and handsome book which killed the old method, but did not, I believe, induce a single observer to adopt the new one which he recommended. I do not for a moment enter the lists with either Dr. Fox or any other chemist; very possibly the discoloration of the test papers was not due to ozone at all. I admit all that, but I will report very briefly what I did in 1856 or 1857, and leave it to the reader to say whether or not it is probable that perseverance in the direction then commenced might not have been rewarded by progress in sanitary work. I cut up a set of ozone papers so that portions of one small strip were simultaneously exposed at several stations, two in the heart of London and Westminster respectively, and the other four or five were exposed in the suburbs. A month's papers were sent out at once all ready dated; at the end of the month all came back to me. Except from smoke, there was not a single day on which the papers exposed in town were discoloured. The suburban ones varied, but according to a regular law the papers in the S.W. suburbs showed ozone, or rather I would say discoloration, with wind from S.W., but when the wind was N. or E. and had to pass over the metropolis there was no discoloration; and so all round. Winds from the country coloured the papers, wind which had passed over the metropolis never did.

FOG.—This is one of the meteorological phenomena hitherto neglected; it is entered in the registers, and sometimes the word dense is added, but that is all. It seems to me imperative that there should be some scale of intensity adopted for fog, just as there is for amount of cloud. Six years since, I wrote a strong plea for the establishment of fog gauges,[1] and suggested the erection of a slab painted as per. fig. 79, p. 180, No. 1 to be $\frac{1}{4}$ inch broad and the higher numbers, $\frac{1}{2}$, 1, 2, and 4 inches respectively, the scale to be 20 ft.

[1] *Symons's Meteorological Magazine*, xvii. 17.

from the observer, and the amount of fog recorded to be that of the thinnest line which could be seen. I do not suggest that the plan is perfect, but regret that no better has been proposed, and that to my knowledge only one observer has adopted it. We shall certainly not learn anything satisfactorily respecting fog distribution until some such scheme is adopted.

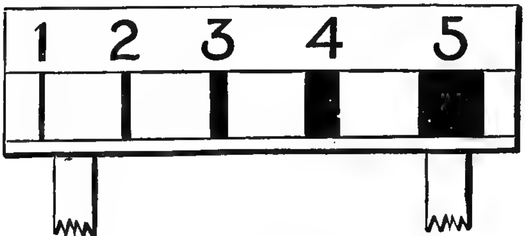


Fig. 79.

Optical Phenomena.—There is much for the meteorologist to do under this head, but as no one could at present prove the relation between, say, aurora and public health, it, and such other subjects as haloes, coronæ, luminous meteors, the three varieties of the rainbow, &c., must pass without notice here, the reader being referred to the short list of useful books at the end of this article if he desires to pursue the subject.

Verification of Instruments

It is always best to insist upon instruments being accompanied by a certificate of verification, the cost of which (except for barometers) rarely exceeds half-a-crown.

OBSERVATION HOURS

These vary in different countries; in the British Isles the hours are almost without exception 9 A.M. and 9 P.M. at the first and second order stations, and 9 A.M. alone at the climatological and rainfall stations. As regards temperature, it is a curious fact that any homonymous hours such as 3 A.M. and 3 P.M., 4 A.M. and 4 P.M., 5 A.M. and 5 P.M., give an average which does not differ widely from the mean of the whole twenty-four hours, and the same is nearly true of the mean of the maximum and minimum temperatures in a Stevenson screen. On the Continent, where people rise earlier, 7 A.M. is very usually the time of the first observation, followed by another about 1 P.M. and a third about 8 P.M., but there is much less uniformity than there is in the British Isles.

Making the Observations

Many hints upon this subject have already been given; it only remains to add a few general ones. In the first place never 'cook' an observation; it is much better to leave a blank, and to give in the margin any information from which you think that you could 'cook' the missing record. The 'cooking,' if it has to be done at all, can be done best at the central office, where other records are available for comparison.

When reading thermometers look quite horizontally at them, otherwise you will read them too high or too low. Take care that you can look comfortably at all parts of the scale of your dry and wet bulb instruments; if they are at all too high, provide a stool or step. Observations not made comfortably are rarely made well.

Be punctual; do not imagine that five minutes after time is of no consequence, or you will let the five grow to ten and the ten to fifteen, and then your unpunctuality will cause more harm than the index error of your instruments.

Always train at least one other person to observe; otherwise, if you are absent or ill, your record will be interrupted, and broken records are of little use.

The Entry of the Observations

This differs so much according to circumstances, that few general rules can be laid down. There is, however, one often neglected, but which experience shows to be necessary; it is that the observations should never be taken on a scrap of paper, an envelope, or a slate, i.e. never on anything which is not to be preserved. If observations are worth making, they are worth preserving; and, however much an observer may intend to faithfully copy the figures into his permanent register, he may lose the scrap of paper, smudge the slate, or make a mistake in copying. Memorandum-books are so cheap that there can be no reason why the original entries should not be neatly entered in pencil in readiness for copying in ink, and then in any doubtful case the original pencil entry can be produced.

The forms of record employed by different societies, institutions, and countries differ so considerably, but are all of them so clearly arranged, that no further explanation seems needed than that on the forms themselves.

The Publication of Observations

This also is a subject upon which there is little to say, because it depends so much on the object with which the publication is to be made. I, however, offer one suggestion, viz. that in many tables too much prominence is given to hygrometric calculations of doubtful value, and too little to daily and monthly ranges of temperature. I by no means advise the exclusion of the dew-point temperature, or the amount of humidity; but, knowing that the foundation (the theory of the wet-bulb thermometer) is doubtful, I think that space can be employed to greater advantage than by devoting columns to 'elastic force of vapour,' 'weight of vapour in a cubic foot of air,' 'additional weight of vapour required to saturate a cubic foot of air,' and 'weight in grains of a cubic foot of air.'

Lastly, I would urge that, wherever possible, values should be given not only in figures but represented by curves and diagrams.

SOME USEFUL BOOKS UPON METEOROLOGY

(I purposely make this heading as vague as possible because every list of the kind must necessarily be imperfect. Where a subject has a literature of many thousand volumes, no two persons would pick out the same fifty as the best; nay more, the same person would probably not twice select the same fifty. It would have been both more easy and more pleasant to make it longer, but anything beyond a very short list would be quite out of place. The title is given in English for all those works of which English translations exist. Where translations are known, the language in which they can also be obtained is indicated by a prefixed letter. F=French; G=German; S=Swedish).

Instructions and Tables

Abercromby, Hon. R.: Instructions for observing Clouds (with photographs). London, 1888.

Blanford, H. F., F.R.S.: Instructions to Meteorological Observers in India. Calcutta, 1876.

Denza, F.: Istruzioni per le osservazioni meteorologiche e per l' altimetria barometrica (2 parts). Torino, 1883.

Glaisher, J., F.R.S.: Hygrometrical Tables. 6th ed. London.

Guyot, A.: Tables, Meteorological and Physical. 4th ed. Washington, 1884.

Hann, J.. Jelinek's Anleitung zur Ausführung met. Beob. New edition in two parts. Wien, 1884.

Hazen, H.A.: Handbook of Meteorological Tables. Washington, 1888.

Jelinek, C.: Anleitung zur Anstellung meteorologischer Beobachtungen. 3rd ed. Wien, 1876.

Kingston, G. T.: Instructions to Observers connected with the Meteorological Service of the Dominion of Canada. Toronto, 1878.

Marriott, W.: Hints to Meteorological Observers. 2nd ed. London, 1887.

Mascart, E.: Instructions Météorologiques. 2nd ed. Paris, 1881.

Poëy, A.: Comment on observe les Nuages. 3rd ed. Paris, 1879.

Scott, R. H., F.R.S.: Instructions in the use of Meteorological Instruments. London, 1875.

Symons, G. J., F.R.S.: Pocket Meteorological Tables. Short and simple rules for accurately determining altitudes barometrically, with sundry useful tables. 4th ed. London, 1890.

General Treatises

Abbe, C.: Treatise on Meteorological Apparatus and Methods. (This forms Part II. of the Report of the Chief Signal Officer U.S.A. for 1887.) Washington, 1888.

Abercromby, Hon. R. Weather. London, 1887.

„ „ Principles of Forecasting by means of Weather Charts. London, 1885.

Bebber, W. J. van: Handbuch der ausübenden Witterungskunde. Stuttgart, 1885.

S. Buchan, A: Handy Book of Meteorology. 2nd ed. Edinburgh, 1868.

„ Introductory Text Book of Meteorology. Edinburgh, 1871.

Capron, J. R.: Auroræ, their Characters and Spectra. London, 1879.

Daniell, J. F., F.R.S.: Elements of Meteorology. 2 vols. London, 1845.

G. Dove, H. W.: Law of Storms. 2nd ed.: translated by R. H. Scott. London, 1862.

Drew, J.: Practical Meteorology. 2nd ed. London, 1860.

F. FitzRoy, Admiral, F.R.S.: The Weather Book. London, 1863.

G. Foissac, P.: De l'Influence des Climats sur l'Homme. Paris, 1867.

Fox, C. B., M.D.: Ozone. London, 1873.

Guillemin, A.: La Météorologie. Paris, 1885.

Hann, J.: Handbuch der Klimatologie. Stuttgart, 1883.

Herschel, Sir J. F. W., F.R.S.: Meteorology. 2nd ed. London, 1862.

Kaemtz, L. F.: Lehrbuch der Meteorologie. (3 vols.) Halle, 1831.

F.G. „ „ Complete Course of Meteorology. (Translated by C. V. Walker, F.R.S.) London, 1845.

Lemström, S.: L'Aurore Boréale. Paris, 1886.

Mascart, E.: La Météorologie appliquée à la Prévision du Temps. Paris, 1881.

G. Modern Meteorology—Six Lectures by Mann, Laughton, Strachan, Ley, Symons, and Scott. London, 1879.

F. Mohn, H.: Grundzüge der Meteorologie. 2nd ed. Berlin, 1879.

Schmid, E. E.: Lehrbuch der Meteorologie. Leipzig, 1860.

F. Scott, R. H., F.R.S.: Elementary Meteorology. 4th ed. London, 1887.

„ Weather Charts and Storm Warnings. 3rd ed. London, 1887.

Sprung, A.: Lehrbuch der Meteorologie. Hamburg, 1885.

Thomson, D. P.: Introduction to Meteorology. London, 1849.

Umlauft, F.: Das Luftmeer. Wien, 1891.

Periodicals

American Meteorological Journal. (Monthly.) Ann Arbor, U.S.A., 1884–91.
Annuaire de la Société Météorologique de France. (Monthly.) Paris, 1849–91.
Annuaire de l'Observatoire de Montsouris. (Annually.) Paris, 1872–91.
Annuaire de l'Observatoire Royal de Bruxelles. (Annually.) Bruxelles, 1833–91
Bollettino mensuale dell' Osservatorio Centrale del R. Coll. Carlo Alberto in Moncalieri (Monthly.) Torino, 1880–91.
Ciel et Terre. (Fortnightly.) Bruxelles, 1881–91.
Das Wetter. (Monthly.) Magdeburg, 1884–91.
Journal of the Scottish Meteorological Society. (Originally quarterly, now annually. Edinburgh, 1863–91.
Quarterly Journal of the Royal Meteorological Society. London, 1872–91.
Symons, G. J.: British Rainfall. (Annually.) London, 1861–91.
Symons's Monthly Meteorological Magazine. London, 1866–91.
Wild, H.: Repertorium für Meteorologie. (Variable.) St. Petersburg, 1870–90.
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INFLUENCE OF CLIMATE ON HEALTH

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CLIMATE

THE influence of climate on health is a very important subject, and often constitutes a difficult problem for governments and sanitary authorities to solve in regard to colonisation, to sites of towns, and to the disposition of troops. It is well known that thousands of lives have been sacrificed to ignorance, on the part of those in authority, of the climatic peculiarities of the regions to which settlers or troops have been sent, while on the other hand military surgeons possessed of climatic information have been able by due precautions to preserve armies in comparative health and vigour, even under the strain of fatigue and privation, and in pernicious climes.

The connection of race and climate is an exceedingly intimate one, and we can hardly doubt that many of the divisions of the human family owe their principal characteristics to the influence of different climates acting through successive generations; for instance, in the Caucasian variety we see the influence of climate well exemplified in the contrast between the natives of Europe and of India; in the Mongolian variety, between the Chinese and the Esquimaux; or again in the difference between the negroes of various parts of Africa, and lastly we may even detect some trace of this influence if we compare Englishmen with their cousins in our colonies, and in the United States of America.

The influence of climate on the individual depends largely on whether he be native or imported from another region, and while in some localities emigration, as in Australia, is attended with no evil results, and the emigrating race even gains in numbers and strength, in other cases it is not so, and the emigrant race dwindles and disappears under the new conditions.

In our great dependency India, which has been ruled so long and so judiciously by Great Britain, it is stated that the pure race, if not intermingled with the native, does not last beyond the third generation, and there are other tropical climates, such as those of the West Coast of Africa and the West Indies, that appear to have a particularly deleterious and fatal effect on the Anglo-Saxon race, and have earned the name of the White Man's Grave. In these regions the natives and especially negroes survive, and sometimes flourish, but it is a mistake to conclude that they are uninfluenced by the climate which is so fatal to Europeans; as a matter of fact they do suffer, but in other ways. At the Cape of Good Hope Hottentot soldiers suffered from pulmonary disorders more than white soldiers. At Sierra Leone black regiments furnished a larger quota of chest disease than white ones in the ratio of 6·4 : 4·9 per 1,000[1] (Boudin). In Jamaica too the Army Medical Report for 1859 states that while not a single white soldier was admitted for tuberculous disease, the deaths from phthisis among the negro troops stood at 8·67 per 1,000 of the whole strength. Negroes seem to be especially prone to phthisis, and when transplanted to a temperate climate, to develope it rapidly, for the Army Medical Reports also show that negro troops when moved from Sierra Leone to Gibraltar, a healthy station for white troops, developed a phthisis mortality of 43 per 1,000 in place of 6·4 at Sierra Leone.

[1] Walshe, *Diseases of Lungs.* 4th edition.

In temperate climates the Anglo-Saxon flourishes and spreads in all directions, as the vast and increasing populations of North America and Australia testify.

It was truly remarked by the late Professor Parkes that much of the mortality of Europeans in tropical climates was due, not to the climate alone, but to the climate *plus* certain other agencies, such as impure water, improper food, bad drainage, and various kinds of excess, and that, if these causes be removed, the mortality of Europeans, or rather of European troops, in the tropics does not differ so greatly from the mortality of troops at home.

The wonderful improvement in the health of troops in India and tropical countries has doubtless been due to a more complete enforcement of military hygiene. However, after making fair deduction for the effect of errors of life, there remains a certain proportion of disease, by no means a small one, occurring among persons of well-regulated life, which can only be attributed to the effects of climate. Before entering more fully on this subject, we will consider the various elements of climate and the influence that each individually exercises on the human body; and then we shall be in a better position to determine the exact part that climate plays in the causation of disease.

Climate is derived from the Greek *κλίμα* (*κλίνω*, I bend), a slope, signifying the curvature of the earth from the equator to the pole, and indicating various qualities of the atmosphere which surrounds us, such as its density, its temperature and sunlight, its moisture and rainfall, its winds and electricity, and all the factors which more or less influence the human frame.

TEMPERATURE

The human body appears capable of enduring great extremes of temperature, and of maintaining its standard of 98° to 99° F. under the most opposite climatic conditions.

It has been shown that inhabitants of temperate climates like Great Britain can endure both extremes of cold and heat without danger if they adopt certain precautions, and provided the atmosphere be still and dry.

The degree of *cold* which Arctic voyagers have sustained without injury is very astonishing. Captain Parry noted the thermometer as low as − 55° F. or 87° below the freezing point, Sir John Franklin at − 58° F. or 90° below the freezing point, and Sir George Back at − 70° F. or 102° below the freezing point.

Sir John Richardson[1] states that in his last Arctic expedition he was accustomed to go from his sitting-room at a temperature of 50° F. to his magnetic observatory at a short distance from it, without feeling it necessary even to put on a great coat, though the temperature of the external air was − 50°, and the difference between the two atmospheres 100° F. He attributed this absence from chilling influence to the dryness and stillness of the air. The writer, when visiting the Engadine in the winter, has often exposed himself to night air, when the thermometer was − 4° F., without catching cold, and both at Davos and St. Moritz it is the custom for pulmonary invalids to sleep with open windows all through the winter, apparently with impunity and even benefit, though in the winter the night minimum is sometimes below − 11° F. This would be impossible if there were much wind.

If the exposure to cold be prolonged, and the circulation and thermogenic powers cannot be maintained, the blood-vessels, and specially the smaller arteries and capillaries, become contracted, and no longer permit the passage

[1] Carpenter's *Human Physiology*. 4th edition, p. 431.

of blood-corpuscles, and thus all physiological and chemical changes are arrested. Various parts, especially the extremities, become starved, and hence death of these parts takes place by frost-bite and gangrene, which show themselves generally in the toes and fingers. Prolonged exposure to extreme cold gives rise to an overpowering sense of lassitude and languor, the sensibility becomes lowered, the individual loses power of reaction and sinks to sleep, often to rise no more, as is sometimes witnessed in long journeys through the snow, the form of death being generally coma. In other cases the brain becomes excited and the patient manifests delirium, incoherence and thickness of speech, the symptoms resembling those of intoxication. Death may occur from syncope or asphyxia, though this is less frequent than by coma.

The influence of heat on the human body, whether it be solar or artificial, does not, as a rule, cause any great rise in the body temperature, provided perspiration be free and abundant, which in old residents in the tropics is generally the case. The balancing power of the human economy over its temperature, through its secretions, is very wonderful, for Blagden and Fordyce bore a temperature of 260° F. in an oven with only the small rise of 2½° F., as long as the air was dry and the perspiration free; but if the air became moist and evaporation was hindered, the temperature of the body rose 8° F.

The effects of the direct sun's rays will be considered later, but various interesting experiments have been made on the effect of heat in shade. Dr. Becher determined his own temperature in a very useful way during a voyage from the Cape to India, and found that the body heat increased in the proportion ·05° F. for every increase of 1° F. in the air. Rattray, in his own case, found a decided increase varying from ·2° to 1°·2 F., the maximum being generally attained in the afternoon.

The effects of the direct sun's rays on the human body are, when not too powerful, highly beneficial, and as we can see in the vegetable kingdom the etiolated plant craning its long slender stalk, and spreading its leaves to catch the welcome sunshine, and, when this is reached, exchanging for transparent stems and absence of colour sturdy growth and an abundance of chlorophyll, so we witness the power of the sun's rays in the contrast between the pallid faces and complexions of dwellers in large cities, and the brown tint and ruddy hue and vigorous appearance of the native of the country or seaside. Though the intimate chemical and physiological effects of sunshine on the human economy may be as yet unknown to us, we recognise its healthful influence in promoting cell changes, in quickening capillary circulation, in stimulating gland secretion, and fostering growth and development. How different to the sensations is the atmosphere of a room where the sun never shines to that of one with a southern exposure, where the mote-laden sunbeams radiate into every corner and remove the dank chill feeling so generally present in sunless chambers, about which the old Italian proverb is only too true, that 'where the sun does not enter, the physician will.' Well has Mrs. Hemans said:

> Thou art no loiterer in monarch's hall,
> A gift thou art, and a joy to all.
> A bearer of hope by land and sea,
> Sunbeam, what gift hath the world like thee?

The effect of heat on the lungs is to diminish the number of respirations, as Rattray showed in persons passing from a cold to a hot climate; there was a reduction from 16·5 respirations (in England) to 13·74, and even to 12·74 in the tropics, accompanied, however, by a slight spirometric increase, not

enough, however, to compensate for the diminished number of respirations, and so the respiratory function is considerably reduced, the reduction amounting to at least 18·43 per cent., or, as Dr. Parkes[1] puts it, 'If 10 ounces of carbon are expired in the temperate zone, only 8·157 ounces would be expired in the tropics.'

There is also a diminution in the water exhaled. The observations of Parkes and of Francis that the lungs of Europeans in India are lighter after death than the European standard, confirm the explanation given by Rattray of the slight spirometric increase, compared with the lessened number of inspirations, viz. that in the tropics there is a larger proportion of air and a lessened one of blood in the lungs. Observations show that the heart's action is not perceptibly quickened in the tropics, and that the pulse is not faster than in temperate regions. The digestive powers are lessened, and the craving for animal food diminished, and there is ample evidence of the liver being first congested, and then undergoing various indurative changes consequent on active or passive congestion of an organ. The skin is stimulated to largely increased action, and there is an increase of excretion estimated at 24 per cent. The urine is diminished in quantity and the amount of urea lessened, possibly from less animal food being consumed. The nervous system is depressed, and specially so if great humidity be combined with great heat. Great heat is well borne by the system if the body temperature is kept down by abundant perspiration, and if the hot season be not of long duration, but protracted residence in a region of great heat appears to exercise a depressing influence, lessening the nervous activity and impairing the great functions of digestion and respiration and sanguification, and the power of forming new and healthy tissue. The tint of the skin and conjunctivæ in Europeans long resident in the tropics, and their appearance of premature age, all go to confirm this conclusion.

HUMIDITY

There are few climatic factors which influence our sensations more strongly than humidity. After several hot days, or after a long succession of east winds, a fall of rain is followed by a pleasant refreshing condition of the atmosphere, which we all appreciate. On the other hand, excessive atmospheric humidity prevents free evaporation from the skin though it often materially assists expectoration, and is therefore useful in many cases of bronchitis. The effect of rain on the circulation may be illustrated by the following: A consumptive male patient of mine was trekking in the Kala Hari Desert in the Cape Colony and apparently flourishing in the open-air life. The climate was exceedingly dry, a difference of 25° F. between the wet and dry bulb being recorded. Heavy rain afterwards fell, the saturation point was reached, and the patient immediately had a severe attack of hæmoptysis. The presence of a large amount of moisture in the air, while it promotes expectoration, rather favours the continuance of coryza and catarrh. The combination of moisture and heat, as is seen in the sirocco wind, is felt oppressive by most people, but it is doubtful if the combination of cold and moisture be not more harmful.

'From the experiments of Lehmann on pigeons and rabbits it appears that more carbonic acid is exhaled from the lungs in a very moist than in a very dry atmosphere.

'The spread of certain diseases is supposed to be intimately related to humidity of air. Malarious diseases, it is said, never attain their fullest

[1] *Practical Hygiene.* 4th edition, p. 402.

epidemic spread unless the humidity approaches saturation. Plague and small-pox are both checked by a very dry atmosphere. The cessation of bubo plague in Upper Egypt, after St. John's Day, has been considered to be more owing to the dryness than to the heat of the air.

'In the dry Harmattan wind, on the West Coast of Africa, small-pox cannot be inoculated; and it is well known with what difficulty cow-pox is kept up in very dry seasons in India. Yellow fever, on the other hand, seems independent of moisture, or will, at any rate, prevail in a dry air.'[1]

RAINFALL

The precipitation of atmospheric moisture in the form of rain may, if not excessive, exercise a beneficial influence on health, as, besides reducing the amount of moisture in the atmosphere, it sweeps away various impurities arising from the presence of man and animals, which would otherwise accumulate, and thus rainfall considerably promotes the health of the community. The amount of rainfall differs in different localities enormously, from almost nothing in the Sahara Desert to 493 inches at Cherraponji[2] in Assam, and its precipitation seems to be determined, according to Mr. Scott, in one of three ways:—

First, by the ascent of a current of damp air which, losing heat in ascending, is unable to hold as much moisture in suspension as formerly.

Second, the contact of warm and damp air with the colder surface of the ground, as in the case of the western coasts of Great Britain and Ireland in winter, where the land is colder than the sea surface.

Third, the mixture of hot and cold masses of air, of which the influence in promoting rainfall is not very considerable.

Examples of the first are to be seen where a warm moist wind is diverted upwards by an intervening mountain range; the current is rapidly cooled in ascending and deposits its moisture in the form of rain. This is still more marked if the wind comes from seaward, and in this way the S.E. trade becomes a rain-bringer to the mountains of Eastern Brazil and the eastern slopes of the Andes.

Owing to the prevalence of easterly winds in low latitudes, the lee sides of tropical mountain ranges are often, according to Wojeikof, better wooded and watered than the western, whereas in the temperate zone the reverse is the case, and it is the western slopes of mountain ranges which are the best clothed with vegetation and verdure.

Where trade winds blow, there is little or no rain unless they blow on to a mountainous coast, and with the periodic shifting of the trade wind areas the dry areas shift likewise, but the descent of the trade wind brings abundant rain, and when the sun is lowest—i.e. in winter. This season of winter rain occurs in the sub-tropical region, extending from latitudes 30° to 40° in both hemispheres, embracing countries bordering the Mediterranean, with Asia Minor and the western part of Persia and Oregon and California in North America, as well as in the southern hemisphere, the Cape Colony, South-West Australia, and the northern island of New Zealand. Exceptions to this rule are certain districts where summer rains prevail instead of winter—as the Eastern States of the Union, the Argentine Republic, China, and Natal, which benefit largely in an agricultural point of view from rainfall when most needed, whereas the other countries are liable to summer

[1] Parkes's *Practical Hygiene*.

[2] Eliot, in the *Quarterly Journal of the Meteorological Society*, 1882, states 40 inches fell in one day at this place.

droughts. North of the sub-tropical region is the region of rain at all seasons, to which Great Britain and Ireland belong, the rainfall depending on the somewhat irregular succession of barometrical depressions and anti-cyclones which are constantly moving over the earth's surface in the temperate zone. The rule about this region is that the western coasts of the continents have autumn rains gradually passing into summer rains as we advance into the interior of the country. According to Dr. Hann, in Europe the Alps divide the region of summer rains from that of the autumn rains of Southern Europe. In North-West France 24 per cent. of the annual fall occurs in summer, and in Central Prussia 38 per cent. In these islands the wettest month on the west coast is January, and the second wettest is October, but the difference between the months is by no means great, and the London monthly rainfall, as calculated by Mr. Scott and Mr. Dines from observations of sixty years, gives October as the wettest month, but shows the difference between this and February, the driest one, to be only 2·74 inches against 1·50 inches. The annual rainfall in different parts of Great Britain varies greatly, being on the east coast 18 to 23 inches, but on the west from 30 to 130 inches; the largest amount of rainfall in one day registered in Great Britain was 5 inches, which fell in Monmouthshire in twenty-four hours on July 14, 1875.

The regions of the globe where most rain falls are certain districts in the equatorial regions of calms, and localities where damp winds meet the mountain ranges and are thus diverted upwards; on the leeward side of these ranges there is usually a dry tract. Examples of localities with large rainfalls are the Khasia Hills in Assam, with Cherraponji; the Western Ghauts, with Mahabuleshwur, the Western coasts of the British Isles, of Norway and North-West America or Southern Chili, and of New Zealand with Hokitika.

On the other hand, the driest regions in the world are those stretching eastward from the Great Sahara Desert through Arabia to Persia; the Great Salt Lake region in North America; the interior of Australia and the Desert of Gobi in Chinese Tartary, and the rainless tract of Peru and Chili between the Andes and the sea. These two last owe their dryness to their being leeward of mountains which have caused the precipitation of any moisture contained in winds passing over them.

Elevation has been shown to exercise some influence over rainfall, and the amount of rain collected increases with the height above the sea, but it has been demonstrated that in India the maximum fall occurs at an elevation of about 4,000 feet, being the level at which the south-west monsoon is cooled just below its dew point. Mahabuleshwur and Cherraponji are about that level; above, the air appears too cold to contain much vapour.

Hann finds that in the Austrian Alps and in parts of Central Europe, the maximum of rainfall in winter occurs at an elevation of 3,000 to 4,000 feet, but that in summer this level is above the highest peaks.

In the British Isles there appears to be no rule of increase of rainfall with elevation: and on the western coasts, especially the Lake District and that of Glencoe in Scotland, which appear to be the wettest regions, more seems to depend on the trend of the valleys or on their confluence, than on their elevation.

BAROMETRIC PRESSURE

The ordinary varieties of barometric pressure at the sea-level have not been shown to influence health considerably, except when combined with other meteorological elements such as those of temperature and moisture,

but when the barometric pressure is lessened to the extent of several inches, as in balloon voyages, or in mountain ascents, or when it is largely increased as in descents in diving-bells, or pneumatic tubes in use for the construction of piers and bridges, such change exercises considerable influence on the circulatory and respiratory system of man.

Diminution of barometric pressure is accompanied by decrease of moisture and by increased power of the sun's rays from the greater diathermancy of the atmosphere—i.e. the increased facility by which the sun's rays are transmitted through attenuated air. According to Dr. Denison this causes an increased difference between the sun and shade temperatures of 1° F. for every rise of 235 feet, and consequently the extremes of temperature are much greater than at sea-level, and the atmosphere is drier and more aseptic, being shown, in some instances, to be devoid of germs. The great heat on mountain sides covered with snow when the sun shines is explained by the before-mentioned diathermancy.

Let us now first consider the effect of diminished barometric pressure due to rarefaction of the atmosphere as we ascend mountains. The barometer which stands at 30 inches at sea-level with appropriate corrections gives at 5,000 feet a reading of 25 inches and one of 20·5 at 10,000 feet, thus, showing a fall of 5 and of 9·5 inches respectively, and these are the degrees of diminution of pressure which are made use of for purposes of medical treatment.

Nevertheless in the Andes people live and flourish at far greater heights. La Paz, the capital of Bolivia, a city of from 70,000 to 80,000 inhabitants, is situated 13,500 feet above sea-level, showing that man is capable of sustaining without injury considerable diminution of barometric pressure.

The effect of extreme and sudden diminution of pressure was seen during Glaisher and Coxwell's balloon ascent, when the reduction to 9¾ inches pressure showed an elevation of 29,000 feet, when Mr. Glaisher lost consciousness though the balloon mounted yet higher, and Mr. Coxwell believed he noted a reading of only 7 inches before the descent commenced, which would indicate a height of 37,000 feet! However, we cannot tell for certain whether Mr. Glaisher's loss of consciousness was due to the cold or to the altitude, but probably from the presence of lividity it was due to the latter. In M. Tissandier's ascent with MM. Sivel and Crocé-Spinelli in the 'Zenith' from Paris in 1875, a height of 8,600 metres (28,155 feet) was reached too rapidly, followed by a descent between 6,000 and 7,000 feet, and then a second ascent to nearly the same height, the result being that all the observers were overcome and lost all power of movement and consciousness, and two died apparently from want of oxygen, presenting cyanosed countenances, with eyes sunk, and mouths open and full of clotted blood, M. Tissandier reaching the ground in an almost unconscious condition. He graphically describes the gradual loss of power in the higher regions, which precluded his using the oxygen inhalations with which he was furnished. The fatal results were attributed not to the altitude but to the rapidity of the ascent, before the lungs could accustom themselves to the altitude—to the long exposure at a great height, and to the inability of the aëronauts to inhale the oxygen gas from sheer loss of power, precluding them even grasping the tubes of the inhalers.

The physiological effects of diminished barometric pressure indicate that for elevations not exceeding 6,000 feet the pulse-rate for natives does not differ from the normal standard, and for strangers there is at first quickening of the normal rate and a diminution at a later date, due to a more powerful cardiac impulse and a stronger vascular system.

With regard to higher altitudes than 6,000 ft., the evidence on the whole

points to a decided increase in the pulse-rate, for Zapater at Janja in the Andes (10,000 feet) and Kellet at Landour in the Himalayas (7,000 feet) found the natives with increased pulse-rate. Denison, of Denver in the Rocky Mountains, lays down a law that the pulse increases 2 per cent. for every 1,000 feet ascended. The influence of diminished barometric pressure on the respiration is more marked. The first effect is an increase in the number of respirations, and visitors to high altitudes often complain of shortness of breath, but after some weeks' residence the lungs becoming expanded and the thorax widened, the vital capacity, as shown by the spirometer, increases, and the respiration rate diminishes and returns to the normal standard or even becomes slower, the respirations being deeper. This would apply to dwellers at moderate altitudes, say under 6,000 feet above sea-level, but in natives of higher altitudes the respiration rate has been noted to be higher than normal.

The tanning of the skin, so marked in high-lying places, is undoubtedly due to the greater power of the solar rays from the increased diathermancy. Another well-marked effect of diminished barometric pressure is the *soroche*, or *puna*, or *mal des montagnes*, which attacks people generally at an altitude of 12,000 feet, and upwards, and appears principally to affect the nervous system. It prevails most markedly in the Andes, and affects human beings and animals on ascending from the sea coast to the higher levels, the bulls for the bull fights being included.

Reviewing the relation of diminished barometric pressure to health, we cannot say that it is injurious, but rather the reverse. The attenuation of the atmosphere and the consequent diminution in the amount of oxygen contained necessitates deeper and fuller, and at first more frequent inspirations, and consequently we get a larger development of the inspiratory organs, and, as an effect, a more vigorous heart and vascular system. Hence the broad and deep thorax, with accompanying well-developed muscles of the mountain races, such as is seen in the Indians of the Andes, in the guides of the Alps, and other mountaineers, who are renowned for their vigour and their great power of endurance during long marches and expeditions. It is stated that the Indians of the Andes can walk 50 miles a day, ascending mountains *en route*.

Increased Barometric Pressure

Our knowledge of the effects of increased barometric pressure on human beings is derived, not from the bottom of mines, where there is undoubtedly increase of barometric pressure, but of too slight a degree to cause any distinct influence, but rather from the results of the compressed air used in diving-bells, diving apparatus, and the caissons or tubes employed in the building of piers, for in these latter men have worked for hours at a time at a pressure of $2\frac{1}{2}$ to $4\frac{1}{2}$ atmospheres, and, when proper precautions were observed, apparently without harm.

The symptoms noticed in descending in diving-bells to a depth of 30 feet were pains in the ears, noises and even deafness, a sensation of tightness as if the head were bound round with iron, these symptoms being more marked if the descent was rapid. At this depth there was no change in the pulse or respiration.

In pneumatic tubes air is pumped in to the extent of 3 or 4 atmospheres, and workmen are thus enabled to remain at work on the foundations of bridges or piers below the level of the water for several consecutive hours. When precautions in entering and leaving the tubes were duly taken, no marked symptoms were noted, but when this was not so, ill effects were observed.

In some works at Douchy, out of 64 workmen, 32 suffered more or less, of whom two died. On the other hand one, an asthmatic, improved in breathing, and another, a chloro-anæmic individual, gained colour. Out of 22 workmen who commenced labour at 4·15 atmospheres, one had slight hæmoptysis, eight experienced muscular pains in different parts of the body, some lasting several days, and one, a man of 40, of robust appearance, who descended the tube only once, died immediately after leaving the tube, the pressure having been reduced to the normal in twenty minutes.

In this case a post-mortem examination showed general cutaneous emphysema, congestion of lungs of specially dark tint, the liver, spleen, and kidneys engorged, and the heart containing dark and fluid blood; nothing abnormal was noted in the brain or meninges.

Compressed air is employed also in the apparatus by which divers carry on operations at depths of 54 metres and less, and it must be remembered that the conditions are not quite the same as in the pneumatic tubes, owing to the additional pressure of the water on the bodies of these men, which at that depth equals 6 atmospheres. Accidents seem more common, and deaths are far from rare. It was calculated that among the sponge divers of the Grecian Archipelago the mortality was 10 per cent., and this does not include the minor accidents. They appear to suffer in much the same way as those who work in pneumatic tubes, only more severely; prickings, muscular pains, and pains in the parts are complained of, the prickings (*les puces*) never taking place where there is much perspiration, and the muscular pains being most marked in the muscles chiefly used by the divers. One diver had epistaxis at the bottom of the sea, which was repeated on a second descent and accompanied by severe pains in the head. The serious accidents consist of paralysis of different kinds, and invariably occur after the diver has left the water. The general form is paraplegia, including paralysis of the bladder and of the sphincter ani. In some cases, the loss of power extends to the upper extremities and is accompanied by loss of sensation over the whole body. Some of the deaths occur immediately after leaving the water, and appear to resemble those which took place in the works at Douchy. A post-mortem examination after one of the deaths from paralysis showed extravasation of blood between the spinal dura mater and the arachnoid, and the greater part of the spinal cord itself was in a condition of softening.

M. Bucquoy made observations on the circulation of workers in compressed air-tubes, and from a large number of instances concluded that in the first increase of pressure in the tube the pulse rises about 20 beats, and that some increase is maintained during the whole stay, the rate falling at the end of an hour to 7 above the normal; and M. Gal's observations on the pulse of the Greek divers exactly corresponds with this, for he found, as a rule, an increase of from 70 to 90 beats. M. Bucquoy also found that the respiratory rate increased temporarily, but that such increase lasted only about 15 hours after returning to ordinary conditions. We must bear in mind that both in pneumatic tubes and in diving the workmen are engaged in arduous labour, naturally involving, even at ordinary levels, an increase in the pulse and respiration rate.

On reviewing the accidents related, it would appear that they were much more due to the reduction of the high pressures, than to the high pressures themselves. Very few unfavorable symptoms appear to have been noted during high pressure in the tubes, and it is marvellous how well high pressures were borne; but most of the accidents occurred either during rapid reduction of pressure, or subsequent to quitting the tubes. In many instances, pressure of 4·45 atmospheres was reduced in three to four minutes to the normal, a pro-

ceeding which has been proved by experience to be fraught with danger. The symptoms seem principally to be due to lesions of the nervous system, commencing with dyspnœa, quickening of the pulse, muscular pains of more or less intensity, and gradually increasing in severity; then come the different forms of paralysis, including loss of sight and hearing, paraplegia, stupor, loss of consciousness, coma, and death. The divers appear to suffer more intensely than the workmen in compressed air-tubes; but among these also the accidents were almost invariably due to rapid diminution of pressure.

When, however, air at lower pressure is made use of, as when healthy individuals are submitted to the action of a compressed air bath of 10 lbs. to the square inch pressure, the results are different, great care being taken to increase or reduce pressure gradually. For this reason a compressed air bath is arranged to last two hours. During the first half-hour pressure is gradually increased, then maintained at the full for an hour, and the last half-hour it is slowly diminished to the normal. The first sensations are noises in the ears, a sensation in the pharynx, relieved by swallowing saliva or fluid, and sometimes pain in the membrana tympani, all these sensations disappearing quickly on the increase, but returning on the reduction of pressure, and depending on the differences in the density of the air on either side of the membrana tympani. The special senses of taste, smell, hearing, are said to be deadened, the voice becomes shriller, and whistling is impossible. The respiration becomes slower, deeper, and more easy, and the thorax increases in circumference, apparently from greater lung capacity. While the respirations fall in number from sixteen or eighteen to four or five a minute, and, as might be anticipated, the relation of inspiration to expiration is changed, and the latter becomes of longer duration than the former. The pulse becomes slower and smaller in volume, but of increased arterial tension (shown by sphygmographic tracings), the capillaries are smaller, the veins less full of blood. The amount of decrease in the pulse varies from four to twenty beats a minute. All experiments go to show that compressed air exercises an intropulsive influence affecting naturally those surfaces most exposed to it, such as the skin and lungs; the blood is thus driven into the organs protected from air pressure, such as the brain, the heart, liver, spleen, and kidneys. The retardation of the pulse is assigned by some to diminished heart's action, owing to the great obstacles the circulation meets with in the superficial vessels. The temperature is slightly raised in the mouth and rectum, but not in the axilla, the urine is increased in amount, and there is more urea excreted by the kidneys, and more carbonic acid from the lungs.

Muscular power is increased, and this was found to be the case both in the compressed air bath and in the air at high pressure in the pneumatic tubes.

WINDS

There is no question that the great aërial movements which prevail under the name of winds play a very important part in the purifying of the atmosphere, and in preventing that stagnation of air which is favourable to bacterial growth and multiplication. They thus are important agents in the promotion of health, for, as the appearance of a great epidemic has been observed to be connected with a very calm state of the atmosphere, so the springing up of a strong wind has often been the signal of its decline and disappearance. So convinced were the ancient Greeks of the beneficial influence of wind to combat disease, that at Girgenti (Agrigentum), in Sicily, the traveller is shown the artificial opening which Empedocles made in the

rock to admit the Tramontana, or north wind, and thus to dispel the malaria arising from the plain below the city.

We have permanent winds, like the N.E. and S.E. trades, blowing towards the equator from the poles to replace the ascending heated air of the tropics, and owing their direction to the earth's rotation, and we have periodical and variable winds due to local causes not always in action.

The permanent winds, like the trades and anti-trades, vary their area of prevalence with the season of the year, but there are other winds which are, strictly speaking, seasonal; as, for instance, the N.E. and S.W. monsoons, which prevail in India and China during certain times of the year, and have been fitly named by Blanford the winter and summer monsoons respectively. The N.E. monsoon corresponds to the N.E. trade, and would be constant, were it not for the special distribution of land and water in the eastern hemisphere. According to Fayrer,[1] the monsoons are caused in the following manner: 'About the commencement of April, when the whole surface of the continent of India becomes hotter than the sea, the rarefied air rises, and is replaced by the comparatively cooler currents, laden with moisture taken up by evaporation from the Indian Ocean extending from Africa to Malacca. This is the S.W. monsoon, which, rising to higher regions, or being intercepted by the mountain ranges, condenses its moisture in rain on the Western Ghâts and on the coast of Aracan. Following a north-eastern course it loses its influence and its rain as it approaches the northern limit of the continent. About October the winds are variable, and there is a reversal of the current, which begins to blow southward, for the most part, as a dry current, till on the Coromandel coast it brings moisture from the Bay of Bengal, which falls as rain on the coast of the Carnatic and Eastern Ghâts, while some parts of India receive a certain amount of rain with each monsoon.'

The S.W. monsoon is accompanied by low barometric pressure and heavy rains.

It would appear, according to Mr. Scott, that in Western Europe the most frequent wind in winter is the S.W., while both in Eastern Asia and Eastern South America it is the N.W.; but these latter regions differ in this respect, that though W. winds come next to N.W. in both cases, in Asia the S.W. comes far behind, while in Eastern North America it blows as frequently as the west winds. Also, looking at the amount of rise and fall of temperature caused by the prevalence of each wind, compared with the mean temperature, we find the S.W., the most frequent wind in Western Europe, is the warmest in Central Europe, raising the temperature 5°·6 F., while the N.E., the coldest wind in Central Europe, lowering the temperature 7° F., is in the west the least frequent but one of the eight winds; whereas, on the eastern coasts of Asia and America the most frequent wind—N.W.—lowers the temperature as much as 4°·5 F., while the S. wind, which raises the temperature more than 10° F., is the rarest of all.

In Great Britain, according to Mr. Glaisher's Greenwich tables, by far the most prevalent wind for all seasons of the year is the S.W., and next, the W., these two prevailing three times more frequently than the N.E., and six times more so than the E. wind; though probably the latter, from the sensations it gives rise to, makes its prevalence more felt. The N.E. is the rarest wind, and next in rarity come the S.E., the E., and the N., separated by no great intervals. As we know well, the W. and S.W. winds in this hemisphere are the result of the equatorial current and Gulf Stream, and are warm and bring rain, whereas the N.E. and E. winds, blowing from the vast continents

[1] *Rainfall and Climate in India.*

of Europe and Asia, and only moistened by passing the narrow strip of the North Sea, are dry and cold.

Allusion must be made to the ordinary land and sea breeze, which is explained by Mr. Blanford[1] on the principles of general atmospheric circulation. He holds that 'when the air over the land is expanded, and raised more or less like a blister, the upper strata slide off towards the cooler sea and produce an increment of pressure at some distance from the land. The air begins to flow from the region of increased pressure towards that where the air is rarefied, and the pressure is in defect; and so we have a sea breeze setting in from the offing; not a wind drawn in by suction and working its way backwards, as would be the case if the particles nearest the heated spot moved first. At night the action is reversed; the air over the land is cooled by radiation and contracts; the isobaric surfaces slope towards the land, and the air above slides down from the sea, sinking over the land and pushing its way out as the land breeze.'

The valley wind (Thalwind) in the Alps and other mountain ranges, which blows up valleys in the morning, is caused by the air of the valley and lower regions being heated after sunrise and ascending the mountain sides; after sunset this is replaced by a wind blowing down the valley, due to the fall of temperature in the valley air from radiation, causing contraction of the lower stratum, and consequently a partial vacuum, which the downward current from the mountains descends to supply.

There are, however, certain local winds of great influence on the health of the countries in which they prevail, which deserve notice.

The Khamseen wind is a hot, dry blast from the desert, laden with sand particles, which blows in Egypt for fifty days in the spring. The Harmattan is another withering desert wind, blowing over the Sahara towards the Guinea Coast, and whose influence is felt in the Cape Verde Islands.

The Simoom is regarded more as a species of whirlwind; it prevails in Arabia, and sometimes buries whole caravans in sand.

The Mediterranean basin and its shores, from their greater warmth in winter and spring, are liable to the prevalence of winds of great power, which blow principally from the north. These are currents of cool air from an upper stratum rushing in to supply the partial vacuum caused by the heated air ascending from the warm area.

The principal are the Bise, or Bora, or N.E. wind, and the Mistral, or Maestro, a N.W. wind. It may be stated with regard to the Mediterranean region generally, that its winds present this marked difference from those of Great Britain and Ireland, that whereas, in the latter, the westerly winds are moist and the easterly are dry winds, in the South of France the reverse is the case, and the easterly winds are the moist ones, as E., N.E., and S.E. (Scirocco), while the westerly, such as the W., and N.W. are remarkably dry winds.

The N.E. wind is a cold blast, coming generally from some portion of the Alps and their subsidiary ranges, and is most prevalent at the end of the Adriatic under the name of the Bora. At Nice the same wind is called the Bise, and is cold, coming straight from the Maritime Alps.

The N.W., or Mistral, is the most powerful wind in the South of France. It appears in the Rhone Valley, first to the east of the Cevennes Range, and sweeps down the valley, carrying destruction to crops, and penetrating to all spots on the Riviera unprotected by mountain ranges, and making itself much felt at Marseilles and Toulon.

It blows over the passes in the Maritime Alps, oversetting carts,

[1] *Indian Meteorologist's Vade Mecum.*

carriages, and heavy diligences *en route*; and lashing the dark blue waters of the Mediterranean into foam and billows, causing storms in the Gulf of Lyons. With all this it is not a cold wind, but a dry one, and the barrenness of the mountains of Provence is attributed to its influence. During its prevalence it is not rare for the wet and dry bulb thermometer to indicate a difference of 10° between the bulbs, and it is always a harbinger of fine weather. The first effect of this wind on visitors is agreeable, from its coolness, but from its dryness it soon causes unpleasant sensations in the nose and mouth, and often pains in the limbs. In consumptives its appearance has been sometimes followed by an attack of hæmoptysis.

The S.E., or Scirocco, is a wind of the very opposite kind to the mistral, as it is warm, and in Italy and the South of France moist, and generally preludes rain, though in Syria it is regarded as a dry wind. It is supposed to arise in the Sahara Desert, and to gather moisture in crossing the Mediterranean, and certainly its character in the different countries over which it blows would support this, as in Malta and Sicily it is hot and very relaxing, while in Corsica it is less so, but when it reaches the Genoese Riviera it has lost some of its languor-giving qualities, and is very moist, but not very warm.

ATMOSPHERIC ELECTRICITY.

Though undoubtedly the electrical condition of the atmosphere exercises considerable influence on the human frame, it is difficult to measure its effects accurately, and to separate this influence from that of other meteorological factors. The crackling of hair, and its tendency to stand on end after combing, during frosty weather, is an example of electric discharge from the human body, and sparks have been seen to issue under certain circumstances. The illumination of the head of the 'parvus Iulus' mentioned in the first book of Virgil's 'Æneid' has been assigned to atmospheric electricity.

According to Quetelet's observations at Brussels,[1] the diurnal march of electricity exhibits two maxima, viz. at 8 A.M. and 9 P.M. in summer, and at 10 A.M. and 6 P.M. in winter, the day minimum being 3 P.M. in summer, and 1 P.M. in winter, and the variations in electricity precede by about an hour those of the barometric range. The maxima occur at the periods of most rapid change of temperature, and the day minimum corresponds with the period of maximum temperature and minimum humidity. It appears that the electrical phenomena in Brussels at any rate are thirteen times more active in January than in July. This coincidence of the electric maximum with the periods of most rapid change of temperature may afford some explanation of the extraordinary degree to which some individuals are affected by change of weather, but what would be most interesting to know, is the extent to which the prevalence of certain winds influence the amount of electricity. 'It is generally stated that the potential of the air is positive, but there are exceptions, possibly depending on the prevailing wind. Clouds are electrified, either positively or negatively, and of course the sign of the electricity recorded close to the ground will be affected accordingly.'

It is not uncommon for persons standing on the top of a mountain or cliff, during a thunderstorm, to become the conductors of electricity passing from the earth to the cloud, and *vice versâ*. The writer once experienced this at the summit of the Piz d'Arzinol in the Val d'Herens in Switzerland, where a thundercloud enveloped himself and his two companions, and all three felt a distinct buzzing in their hair, like that of insects, which ceased

[1] Scott, *Elementary Meteorology*.

immediately when a descent was made from the summit. Mr. F. C. Smith and his friends noted on the top of the Piz Languard a crackling sound, and on raising their alpenstocks points upwards felt the electrical currents passing through their bodies, and heard the crackling as these passed into the sticks. They also experienced the sensation strongly in their temples and their finger ends. Far more serious than these phenomena are the accidents from lightning which occur frequently and are occasionally fatal.

According to M. Boudin[1] and others, the principal lesions are loss of consciousness combined with paralysis, more commonly affecting the lower limbs than the upper, burns, skin eruptions, often eczema or urticaria, loss of hair in various parts of the body, wounds, hæmorrhage from the mouth, nose, or ears, loss of sight, smell, hearing, and taste, though exaltation of these senses has been known to occur.

If the individual struck does not die immediately from the effects, he may be expected to recover. The lightning generally, as might be anticipated, takes the line of any metal about the person. It is generally the watch-chain or watch which is shivered or melted, and next it is attracted by the nails in the boots, thus reaching the earth. A most interesting case of lightning injury was shown at the Clinical Society[2] by Sir James Paget from the practice of Dr. Wilks of Ashford, where a labourer, when struck by lightning, had his clothes stripped off him by the current, leaving him stark naked, and severely burnt in various parts of his body. The clothing in contact with metal, such as the watch or watch chain and nails in boots, was completely charred. The fact of the clothing being wet, and therefore a good conductor, doubtless in this case led to more extensive burning than otherwise, and conduced to the freedom of the man from nerve lesions.

It was found that where flannels touched the skin, the burns were superficial, but where the cotton trousers came into contact with it, the burns were uniformly deeper.

Classification of Climates

Having considered the elements of climate in relation to health, we can now deal with the influence of the different kinds of climate on human life.

First we must adopt some form of classification of the various climates of the globe, and indicate as far as we can their geographical limits, giving such description of their chief features as may be necessary by way of explanation.

It is impossible to classify all climates according to latitude alone, for various influences, such as warm sea currents and mountain ranges, considerably modify the effects of latitude; nor again can we take isothermal lines as our sole basis of division, for these vary with the season and the month, and the isothermal lines of January differ from those of July. Then again the relation of a region to the sea coast is most important, as in a tropical country bordering the sea the great heat is tempered by saline breezes night and morning, thus rendering it tolerable to human existence, while in the interior the heat may be extreme, as at Marsak in Fezzan, where an air temperature of 130° F. was registered, and at Cooper's Creek in Australia, where Burke and Wills died, and where after their death a thermometer graduated up to 127° F. left in the fork of a tree was found to have burst by the expansion of the mercury,[3] but on the coast the temperature is lowered.

The change of temperature is of course a most important feature of

[1] Holmes's *System of Surgery*, p. 398. [2] *Clinical Society's Transactions*, xiii. p. 32.
[3] Scott, *Elementary Meteorology*, p. 341.

climate, and the regions of greatest annual range are situated within the areas of the northern hemisphere. Near Jakutck in Siberia we find a small district with the enormous range of 100° F., Jakutck having a temperature of 65° F. in its warmest and —44°·9 F. in its coldest month. Dr. Supan[1] has established several laws as to the distribution of the annual range of temperature, among which are the following :—

1. The range increases from the equator towards the poles, and from the coast towards the interior of the continent.

2. The regions of extreme range in the northern hemisphere coincide approximately with the districts of lowest temperature in winter, and the range curves resemble in their course the isotherms of January.

3. The range is greater in the northern than in the southern hemisphere.

4. In the middle and higher latitudes of both hemispheres, with the exception of Greenland and Patagonia, the western coasts have a less range than the eastern. This is mainly attributable to the general prevalence of westerly winds with the moisture they bring with them, and to the set of warm ocean currents on these shores.

5. In the interior of continents, the range in mountainous districts diminishes with the height above the sea. This appears to be due to the cold air in calm weather sinking to the lowest level of the valley, and also that mountain sides are less liable to the visitations of fogs than the vales below.

The effect of warm ocean currents on the temperature of certain regions is best seen in the influence of the equatorial currents in the Atlantic, Pacific, and Indian Oceans. These currents, flowing from east to west, are the result of the east trade winds, producing a general movement of the surface water from east to west along the equator. In the Pacific Ocean this equatorial current flows till it meets the coast of New Guinea, when it divides and is deflected into two streams, one flowing southwards and striking the coast of Australia, and the other northwards, becoming the Kuro Siwo current, or the Great Black Stream of the Japanese seas, which flows outside the Philippines, Loo Choo Islands, and Japan, and returning eastwards to North America, washes the southern coast of Alaska Promontory, the northern side being bathed by the cool current coming out of Behring's Straits. The effect, according to Von Baer, is that humming-birds are met with on the southern shore, while the northern one is frequented by walruses. The freedom from ice enjoyed by the harbour of Sitka and the coasts of British Columbia, while the shores of Asia in corresponding latitudes are fast bound in it, is due to the presence of this warm current,[1] which passing down the American coast eventually rejoins the equatorial drift current. In the Indian Ocean the water is embayed on the northern side, but the main portion of this part of the equatorial current passes to the south of the line and divides opposite to the Island of Madagascar, flowing on either side of it, the inner stream forming the warm Agulhas current, which washes the eastern coast of the Cape of Good Hope. The most important, however, is the Atlantic equatorial current, which, flowing eastwards, divides off Cape Roque, one portion turning southward along the coast of Brazil and slightly deflecting the isotherms of that region, and the other and larger portion, following the north-east coast of South America, combines with the westerly current of the north-east trade, enters the Caribbean Sea and reaches the Gulf of Mexico, whence it issues through the Straits of Florida as the Gulf Stream, a majestic current upwards of 30 miles broad and 2,200 feet deep, with an average velocity of four miles an hour and a temperature of 86° F. It follows the line of the American

[1] Scott, *op. cit.*

coast to Cape Cod, abutting on the cold Labrador current, which is 30° F. colder, and then, taking an easterly direction, spreads over the North Atlantic at a somewhat diminished velocity, and in the meridian of the Azores bifurcates into two streams, one flowing to the right along the coast of Portugal, towards the Cape Verdes, and the other moving onwards to Northern Europe, skirting the coasts of France, Great Britain and Ireland, and Scandinavia; then rounding the North Cape, it passes the White Sea and Sea of Kara along the western shores of Nova Zembla and Spitzbergen, and it is stated that its influence can be traced into Behring's Straits. The current moves slowly off the British coast, according to Mr. Scott not more than an inch or so per second, but that, aided by the westerly winds which it probably originated, it does move, is proved by the drift-wood and tropical products from the Gulf of Florida which are washed upon our shores, and even on the shores of Spitzbergen.

A glance at any map of the isothermal lines for January (see woodcut)

ISOTHERMS OF NORTH ATLANTIC. [WINTER]

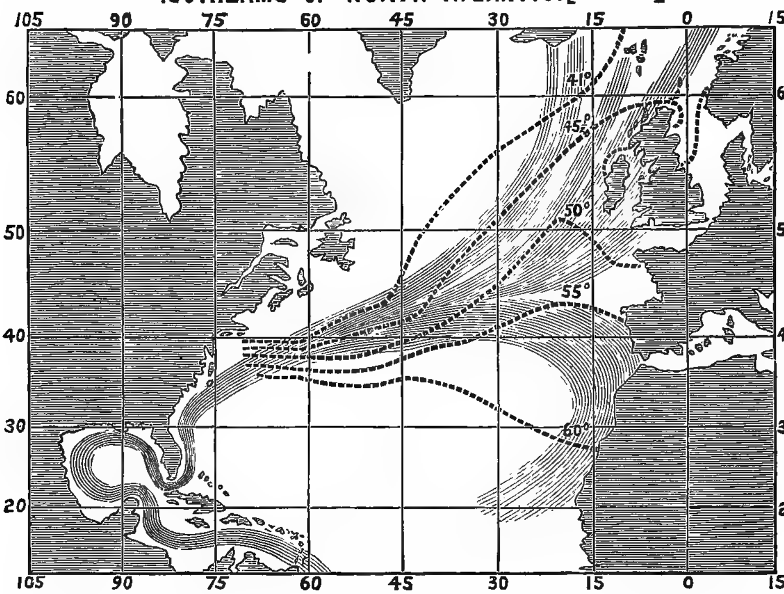

Fig. 80.

will show the enormous warming influence of this current, for the isotherm of 41° F. runs through the American coast near Philadelphia (latitude 40°) and slants in a north-easterly direction between Iceland and the Faroe Islands (lat. 62°). The isotherm of $45\frac{1}{2}$°F. starts from the American coast at about latitude 38°, and runs to the north of Scotland and Ireland, and far up into Norway beyond latitude 60°, the warm current thus causing a diversion of the temperature lines towards the north of upwards of 20° of latitude. It is in consequence of this warming influence that Great Britain and Ireland escape the long and severe winter of Labrador, and enjoy their comparatively mild climate, a climate marked by great equability, especially on the coast line, but, as the heating source is a moist one, by a large rainfall.

Another considerable modification of the effect on climate of latitude is altitude; for, as Herschel says, in ascending a mountain from sea-level to the limit of perpetual snow, we pass through the same series of climates, as far as the temperature is concerned, that we should by travelling to the polar

regions of the globe, and we thus see cities like Quito in South America, in proximity to the equator, but at an elevation of 10,000 feet, enjoying all the year round a climate of perpetual spring; and, again, the mountain sanitaria of Madras, at elevations varying from 5,000 to 7,000 feet, though situated within the tropics, afford a safe retreat for Europeans in the hot season, with a mean temperature varying from 50° F. to 70° F. and with a moderate rainfall.

The presence of mountain ranges exercises great influence first on the rainfall, and secondly on the shelter from winds.

Districts placed to the lee side of great mountain ranges are often sheltered from any powerful wind which may prevail, as is the case with the town of Pau in the Pyrenees, which, lying immediately at the foot of the great Pyrenean range, is sheltered from southerly blasts, while the slanting hills of Les Landes to the north protect it so effectually that the winds from the north pass over the town, striking the Pyrenees on the other side. Wind is almost unknown at Pau; the leaves of the trees hardly move, and rain often falls vertically to the soil.

Accepting the principle of latitude with these modifications therefore, we would roughly class climates as follows, somewhat after the method of Dr. Henry Bennet.

1. *Warm Climates: Equatorial; Tropical; Subtropical.*—Climate of regions lying between the equator and 35° latitude N. and S. Characterised by high temperature, with (as a rule) heavy rainfall, and dry and rainy seasons.

2. *Temperate Climates.*—Climates at regions lying between 35° and 50° latitude, with four well-marked seasons—a preponderance of rainfall in autumn and winter—having a mean temperature from 50° F. to 60° F. and considerable extremes.

3. *Cold Climates.*—Climates of regions lying between 50° and the poles, marked by gradual reduction of temperature as the pole is approached, the greatest cold being 10° from it. The season there consists of a long winter of ten months and of a few weeks of summer. Rainfall small and generally in form of snow. Aurora borealis frequent.

4. *Marine Climates.*—Characterised by the presence of the marine influence—i.e. coasts, islands, peninsulas washed by the ocean or salt seas, and owing their freedom from extremes to warm currents and the equalising influence of the ocean. Such is the climate of Great Britain, Ireland, of Norway, and of many islands. We also include in this division the climate experienced in sea voyages.

5. *Mountain Climates.*—Characterised by diminished barometric pressure, increased diathermancy, and by extremes of temperature.

Warm Climates, extending from the Equator to 35° Latitude, i.e. $12\frac{1}{2}$° beyond the Tropics

This division comprises the greater part of Africa and its islands, South Asia, embracing India and China, Polynesia, including all Australia except Victoria, North America south of California, and South America north of Uruguay, with the West Indies.

It can be subdivided into equatorial, tropical, and subtropical groups, and in the equatorial the mean annual temperature is from 80° F. to 84° F., the minimum being 54° F. and the maximum 118° F. The mean temperature decreases slowly as we recede from the equator, the decrease not amounting to more than 2° F. for the first 10° lat. The difference of temperature during the day is slight, but there is a fall at night from radiation. There is regular,

but slight, diurnal barometric variation, the rainfall is about forty inches, and it is evidently this which tempers and reduces the otherwise extreme heat, as it is not found that the highest temperatures or the highest mean annual temperatures have been recorded at the equator, but at or near the tropics.

The line of perpetual snow is also higher at the tropics than at the equator. The hottest known regions of the world are on the banks of the Senegal, the Tehama or coastline of Arabia, and the deserts in the interior of Australia, and yet none of these are situated on the equator, though all within the tropics.

These facts are explained partly by the unequal progress of the sun after the equinox, and partly by the prevalence of rain at the equator, attributed to the meeting of the north and south trade winds in the upper atmosphere, and consequent precipitation of moisture. This is said to be most marked in the region of calms (equatorial) in the Atlantic and Pacific Oceans, where the rainfall is generally heavy.

In India, according to Blanford and Fayrer, the tropical rainfall depends on the physical features of the country and the monsoon winds. There is a district of low rainfall, chiefly consisting of low hot plains, where the amount does not exceed fifteen inches and sinks in one part to two inches; and there are regions where the south-west monsoon strikes mountain ranges like the Khasia Hills and the Western Ghauts, where it rises to 493 and 253 inches respectively.

Prevalent Diseases

In hot climates, the organs most liable to disease are naturally those which, owing to the special conditions, are overworked. The lungs and heart are but little taxed, and, according to Parkes, are considerably lighter after death than in temperate or cold climates, showing dwindling of structure, probably from partial lack of function, while the liver, spleen, and intestines are all more or less the seat of increased function, and hence are liable to become diseased. The skin, which is often stimulated to increased secretion in tropical countries, is continually bathed in perspiration, and sometimes becomes in new arrivals in the tropics the subject of *lichen tropicus*, an affection characterised by great local hyperæmia and swelling of the papillæ.

The effect of great heat on the system generally, and on the brain in particular, is shown in sunstroke, but its influence on particular organs is more difficult to define, because it is usually combined with other causes of disease, such as malaria, the drinking of impure water, and the consumption of improper food and various forms of excess.

Whilst a great many diseases are assigned to the influence of warm climates, some are wrongly so attributed, but we think that we may fairly ascribe to this cause the following, which appear to have their birthplace within the tropics, even though they may spread at a later date to more temperate regions. Such are sunstroke, yellow fever, dengue, cholera, liver abscess, dysentery, and various kinds of intermittent fever.

Sunstroke.—The exact amount of influence that the sun's rays exercise in the causation of sunstroke is not always easy to determine, because in many cases there are other conditions present, such as a hot close atmosphere, or the body overheated by exercise and unrelieved by perspiration; but it is curious to note the rarity of sunstroke in mid-ocean, even in the tropics, and at high altitudes, and yet in both of these situations the solar rays are exceedingly powerful, though the temperature of the atmosphere in either case is never excessive. The great heat of the sun's rays at high altitudes depends

probably on the rarefaction of the atmosphere, to which is due the unequal diffusion of the heat and great difference between sunshine and shade temperatures. In the Alps this is more marked in winter, when the ground is covered with snow, and the sun's rays are largely reflected from the surface. The following table of observations on the solar radiation thermometer (black bulb *in vacuo*) shows the mean maxima for the four winter months at Greenwich, Cannes, and Davos during the years 1878–9, and indicates the sun-power at a high altitude to be even greater than on the sunny shore of the Mediterranean :—

—	Greenwich	Cannes	Davos
November, 1878	79°·9	122°·0	157°·0
December, 1878	61·0	105·0	147·0
January, 1879	63·8	119·0	141·0
February, 1879	81·4	121·0	166·5

The contrast between sunshine and shade at high altitudes is best exemplified by the following experiment, which was made at Davos.

In December 1878 the writer was sitting with a friend after luncheon, about 2 P.M., in the verandah of one of the hotels, sipping coffee. The sun was shining brightly and they felt quite warm, though snow lay all around them. He placed his cup of coffee in the shade, and moved away to assist his friend, who was trying to light his cigar by concentrating the sun's rays on it with a burning glass. He succeeded in doing so, and the writer returned to his coffee, to find it frozen !

Sunstroke, or Insolatio, is generally the result of exposure to solar or artificial heat, and occurs chiefly in tropical countries, but occasionally in temperate climes. Sir Joseph Fayrer [1] states that the most frequent cases are those coming on in houses, barracks, and tents, by night or in the day away from the solar rays, and the subjects of sunstroke are more likely to be those debilitated by disordered health, by dissipation, and by over-fatigue, than those of vigorous constitution, or who have undergone acclimatisation. Hindoo natives on their bare heads and necks endure an amount of sunshine which would be fatal to a European ; but if the temperature rise above a certain standard all succumb, the natives of India suffering like others, and dying from the effects of *loo-marna*, or ' hot wind stroke.'

Fayrer gives three varieties of sunstroke.

I. Showing itself in exhaustion, and failure of the heart's action in syncope.

II. A condition of shock, in which the nerve-centres, and especially the respiratory, are affected, causing rapid failure of the respiration and circulation.

III. Intense pyrexia due to vasomotor paralysis, and to the nerve-centres being over-stimulated and then exhausted by the action of heat on the body generally.

From the first form recovery is frequent, but the second or asphyxial form, sunstroke proper, is more serious, and is generally due to the direct action of the sun's rays on the head and spine. The brain and nerve-centres, especially the respiratory nerve-centre, are overwhelmed by the sudden elevation of temperature, and respiration and circulation fail, the failure of the latter being due to the inhibitory influence of the vagus ; the heart after death being found contracted. The symptoms of this form are generally those of violent injury to the nerve-centres, unconsciousness and cold skin, feeble pulse, and death from rapid failure of respiration and circulation.

[1] Quain's *Dictionary of Medicine*. Article ' Sunstroke.'

The third form, the so-called 'heat fever,' is an intense state of feverishness, the effect of heat on the nerve-centres, and through them on the vasomotor system, resulting in the raising of the body temperature, generally by heat, solar or artificial, as it may occur independently of the direct solar rays. This form comes as frequently at night or in the shade as by day, especially in persons exhausted by fatigue, dissipation, or overcrowding in an impure atmosphere.

According to Fayrer, from whose admirable article most of this description is taken, the body temperature rises to 108° F., 110° F., or even higher, the brain, medulla, and cord, the nerve-centres generally, and especially the respiratory, suffer from over-stimulation, followed by exhaustion : respiration and circulation fail, there is dyspnœa of a hurried gasping kind, great restlessness, thirst, fever, frequent micturition and pungent heat of skin, which is sometimes dry, sometimes moist. The pulse varies, being sometimes full and laboured, sometimes quick and jerking, the face, head, and neck are congested to lividity; the pupils, at first contracted, may dilate before death. Delirious convulsions (often epileptiform), coma, relaxation of the sphincters, suppression of urine, prelude the fatal termination, but not infrequently partial recovery takes place, to be followed later by relapse and death. The mortality of sunstroke is about 45 to 50 per cent., but, of those who recover, many are permanently injured, either in brain power, or in the general health, and we find as a result impairment of memory, nervous irritability, headache, and even epilepsy, partial paraplegia, partial or complete blindness, and extreme intolerance of heat, and especially of the sun's rays.

In fatal cases of sunstroke, the lungs and the pulmonary system are often deeply congested, the heart is firmly contracted from coagulation of myosin, the venous system is gorged, and the body marked by petechiæ. The blood is more fluid than usual, acid in reaction, the globules have less tendency than usual to form rouleaux, and are deficient in oxygen. The body for some time after death retains a high temperature, and the viscera when first opened feel pungently hot, and the incisions drip dark blood.

The brain and membranes are intensely congested, and sometimes there are serous effusions into the ventricles, and sometimes hæmorrhage into the brain substance ; but the cause of death is generally asphyxia, but apoplexy and the most important changes are found in connection with the thoracic viscera.

Yellow fever may be said to be limited to subtropical and tropical countries, as it is only found between 32° 70′ north, and 22° 5′ south latitude. It prevails in the West Indies, the Gulf of Mexico, extending to the southern of the United States of America, and in South America, as far south as Rio Janeiro. It has at times also crossed the Atlantic and prevailed on the West Coast of Africa, between Cape Verd 14° 54′ N. latitude, and Cape Coast Castle, 5° 7′ N. latitude, and has extended to the ports of Western Europe; cases have also been seen in the Northern States of America. Its relation to climate is singularly distinct. It requires, for its existence and diffusion, a temperature of not less than 70° F., and it is increased by moisture, and thus it can only prevail during hot and moist seasons. Nevertheless, it is extinguished by a heavy rainfall, by cold winds, or by frost or snow. As a rule it is confined to the sea-level, and only rarely, if ever, is found at any height, though it has on one occasion been known to invade towns at considerable elevation in the Andes. It chiefly infests seaports, and for the most part the worst and most crowded quarters, and it spreads almost entirely by infection, and generally attacks strangers coming from northern climates in preference to natives. Acclimatisation gives immunity for one region, which

however, may be lost by a change of residence to another country. Negroes and Chinese seem exempt from this disease.

Prevailing as yellow fever does in tropical countries and almost solely in crowded cities on the seaside or the banks of rivers, it is probably due to a poison generated or fostered by local pestilential conditions, and in many districts improved sanitation has reduced, and may still further reduce, its prevalence.

Dengue is another disease confined to the tropics, and prevails between 37° 47′ N. and 23° 28′ S. latitude, in summer and early autumn. It has appeared as an epidemic in the West Indies and Central America, but it occurs principally in India, China, and Egypt. It is an infectious fever characterised by severe continuous arthritic and muscular pains, debility and prostration, an initial and terminal rubeoloid or scarlet rash, pyrexia rising to 103° F. or even 105° F., but speedily declining, though subject to remissions or relapses; pain and swelling of joints and glands, and orchitis, and visceral complications, such as diarrhœa and dysentery, and boils are also common symptoms.

Its period of incubation is five to six days, and the duration of the complaint, when free from sequelæ, about eight days; but it is sometimes prolonged to weeks, and like influenza, which it is said to resemble, it often leaves the patient in a very weak and shattered condition.

Dengue has appeared occasionally in a more severe form than the above, with symptoms of hyperpyrexia, coma, cyanosis, and œdema of the lungs (Charles), but as a rule it is not a fatal disease. It never occurs in England, and from its appearing as an epidemic and spreading over large tracts of country without any apparent reason, its development has been assigned to some unknown cosmic and atmospheric conditions (Fayrer).

Asiatic cholera, though its epidemics are diffused over nearly the whole globe, tropical, temperate, and cold countries being visited in succession, has its home in India, where it is endemic, in a region which has been described by Bryden as bounded on the east by the 91st or 92nd parallel of longitude, on the west by the 81st parallel, on the north by the latitude of 27° N., and on the south by the shores of the Bay of Bengal (including the delta of the Ganges and the territory at the mouths of the Mahamuddy). This region extends from the mountainous districts of the Brahmapootra to the hill regions of Rajmahal and Cuttack, and on its northern border along the Terai from Lower Assam to the district of Purnea. Of this region the delta of the Ganges with a very high annual temperature is assigned as the focus of cholera, and the cholera mortality of the Presidency of Bengal is the greatest in India, the eastern portion of the district being most frequently attacked. Cholera becomes virulent and spreads from this centre often to other parts of India and eventually to other countries of Asia, to Africa, and to Europe and America, North and South; apparently choosing the great lines of human intercourse for its channel of diffusion; but, what we as climatologists are most concerned with, choosing the warm and rainy seasons for its march, and rapidly disappearing on the approach of cold weather. The disease generally travels westwards and somewhat slowly, but it has been proved to be conveyed by both sea and land-routes. The infective material has been proved to be principally contained in the alvine excretions, which, becoming mixed with the water-supply of a city or town, may rapidly poison a whole community, the smallest quantity of the infective material imparting to enormous volumes of water the power of propagating cholera (Simon). The disease may also be communicated directly by cholera patients in crowded and badly ventilated rooms, as well as from their soiled linen.

Seaports are generally attacked by cholera, and a saline atmosphere affords

no protection ; but, on the other hand, it is ascertained that a certain altitude above sea-level has often been shown to confer immunity, and in India it is the practice to remove troops to hill stations when the disease breaks out.

Switzerland was exempt during most of the great epidemics, and both in England and France it was found that more or less elevated districts suffered far less than low-lying ones.

The diffusion ot cholera appears to follow the course of rivers, and Hirsch holds this to be due to the more copious saturation of the ground, coupled with the retention of organic matters undergoing decomposition, and he remarks that one of the best proofs of this is, that the amount of sickness diminishes in proportion as the disease in its progress travels further from the margin of the river basin.

Dysentery, Diarrhœa, and Tropical Abscess of the Liver.—These diseases have been placed together in the same category as apparently due to similar causes, and forming in many patients various links in the same chain of pathological events. How far they are due to tropical climates alone, or to the influence of malaria or to impure drinking water, is not always clear, for in many instances all these factors are at work together, and unquestionably a good supply of drinking water has lowered the death-rate from diarrhœa and dysentery in many tropical countries, as much as a reduction in the quantity of alcohol consumed by English troops has diminished the number of cases of hepatitis and liver abscess.

The connection of malaria with dysentery has always been strongly held by some Indian surgeons, who are able to point to the fact of both diseases diminishing and often disappearing under the efficient draining of swampy districts ; but the opinion gains daily that though dysentery may be due in some cases to malaria or to any poison congesting the portal system and the spleen and the liver, the greater part of dysentery arises from other causes, such as impure water, bad drainage, and especially the accumulation of dysenteric stools, and improper food. Hirsch, too, considers that it is neither 'in high temperatures, nor in an extreme range of the thermometer inducing chills, that we have to look for the endemic factor of dysentery and diarrhœa,' though he admits ' that extreme fluctuations of the temperature (in so far as they induce chill) are among the most inviting opportunities for the malady to start.'

Nevertheless, whilst admitting that dysentery may occur in any country or clime under special circumstances of bad water, food, and drainage, as has been repeatedly demonstrated in outbreaks during campaigns, we cannot disguise the fact that it is far more common in tropical climates than in temperate, and we must accept heat, though not necessarily moisture, as an element, though not as an absolutely essential one, of its causation.

Abscess of the liver, though known in temperate and cold climates, where it is a rare, and, for the most part, a secondary disease, is tolerably common in the tropics, and especially in India, where it forms a conspicuous feature in the disease statistics of both the European and native troops, and is partly due to the extreme heat to which they are exposed, and partly to alcoholic excesses.

Malaria.—This poison is found in operation not only in tropical, but in temperate climates, though not in cold ones, but as it is far more common and reaches its greatest point of concentration and virulence in tropical climes, we have selected the division of warm climates for its consideration, alluding in passing to its manifestations in temperate climates. Though some advance has been made by recent investigations in our knowledge of the intimate nature of malaria, it cannot be said that full explanation has

yet been given of the variety of conditions of soil and atmosphere under which it prevails, the conditions being often of an almost opposite character, as, for instance, in India it is found in the water-logged marshy ground of the Terai, and also in the sandy dry soil of the Deccan. The presence of water, and especially of salt water in large amount in a marsh, appears to reduce the malarious influence, but the drying up of a marsh, or of a river bed, or the subsidence of a flood, is generally the signal for an outbreak of intermittent fever.

According to Dr. W. Maclean, the remittent fever which devastated the British army in the Peninsular War, when encamped on the sunburnt plains of Ciudad Rodrigo, may be explained by these plains having been the scene of floods, which had recently dried up under the scorching sun of a Spanish summer. Fayrer considers that subsoil water or damp is the most essential condition of malaria, and especially if the subsoil be impregnated by a certain amount of stagnant moisture, and that this is probably present in many of the localities in which the appearance of malaria is so difficult of explanation.

According to him, malaria is at its worst in India in the drying-up season after the rains, but during the rains it is less severe. The turning up, or excavation of new soil, generally increases the danger, but the cultivation, draining, and cropping of the same soil generally diminishes or abolishes it.

Parkes gives as examples of soils with the largest organic emanations, and therefore most likely to be the source of the malaria—

1. Alluvial soils, old estuaries, and deltas.
2. Sands, if there be impermeable clay, or marly subsoil, and old water-courses.
3. The lower parts of chalk, if there be a subsoil of gault or clay.
4. Weathered granite trap rocks, if vegetable matter has become intermixed.
5. Rich vegetable soils at the foot of hills.

Klebs and Tommasi-Crudeli discovered in the air and soil of the Roman Campagna a microscopic fungus, consisting of numerous moveable shining spores of a longish oval shape. This 'bacillus malariæ,' as it has been called, is capable of artificial cultivation in suitable media, and when injected into dogs produces well-marked symptoms of intermittent fever, and their spleens are shown to enlarge. The bacillus malariæ has been detected in the blood of human patients, during the period of invasion of the fever, but during the acme it disappears, and spores only can be discovered. It has also been found in the spleen of human subjects, and in the marrow of the bones of the animals inoculated. The conditions of growth of this bacillus are heat and moisture. The proof of malaria residing in the soil is shown by the fact that shutting off the soil by paving, as has been done in Rome, abolishes the malaria, and even when the sun's rays are intercepted by fog or cloud the fever is lessened.

Apart from other elements, heat seems in all climes to be the determining cause of malarious fever, whether remittent or intermittent, as the cases of ague occurring in England, in Essex and Lincolnshire, are developed during the summer and autumn, and on the shores of the Mediterranean tracts of land which would be exempt from malaria in this country become teeming with miasm under the influence of the powerful southern sun. This is the case of the deltas of rivers in the south of France and Italy, and the embouchures of streams in Corsica and Sardinia. In some places, as at the mouth of the Var, the embanking of the river has, by raising the river bed, developed malaria among the dwellers on either side.

On the west coast of Corsica, the streams discharge into the sea by rocky channels, the greater part of the coast being of that character, and there only exist small deltas at their mouths, but these under the solar influence produce malaria in the summer, which is wafted by the westerly winds up the mountain valleys for a considerable distance. It is held by many authorities that the summer isotherm of 58° F. to 60° F. limits the occurrence of intermittent fever, and that regions where the mean summer temperature does not reach this figure are exempt from malaria, a conclusion abundantly proved by evidence ; and Hirsch remarks that confirmation of this is notably found in the fact that the extent and intensity of the disease in malarious foci at the different seasons of the year are in direct proportion to the height of the respective temperatures, and also in the fact that the great epidemics and pandemics have been immediately preceded by hot years, or have coincided with them.

The effect of malarious poison on the human system is as conspicuous as its action is insidious. First we get the nervous system attacked with neuralgic migraine, or some other form of nerve storm ; then comes asthma, another neurosis so commonly associated with malaria. And later the morbid changes in the spleen and liver, and in time those degenerative changes in the tissues which give to the patient the appearance of malarious cachexia. As the poison increases in intensity, and the climate becomes hotter, we get fever, at first intermittent, quartan, tertian, and quotidian, and further south we find the remittent form so common in the tropics.

Fayrer teaches us that natives of India are attacked quite as much as Europeans by malarious fever, and even that dogs, and horses, and cattle are affected. The mortality of British troops in Bengal from fever is less than 3 per 1,000, but that of the natives is nearly 25 per 1,000, and the difference is attributed to the natives being poorly fed and badly housed.

We will now close our account of warm climates and their influence on health, having indicated the principal, though by no means all, the diseases which are assigned to them, with the conclusion that for Europeans who have gone through the ordeal of such complaints, and survived them, change of climate, and especially a return to their own temperate climate, is the best means of restoring health.

The climate of the desert forms an important sub-group of warm climates, and, as it is a good example of the combination of warmth and dryness, it merits a few words of special description. As an instance may be cited the tract commencing with the Great Sahara and extending eastwards through Arabia to Persia, and therefore including the Egyptian desert ; other examples are the desert of Gobi in Chinese Tartary, the Kalahari in South Africa, the Great Salt Lake district in North America, and the vast deserts in the interior of Australia.

Let us take Egypt as a type of the desert climate, including its principal features.

First, its dryness. The rainfall at Cairo is 1·22 inches, occurring in occasional showers lasting 15 to 30 minutes, seldom longer. At Thebes rain is exceedingly rare, and in the province of Esneh it is almost unknown. The number of days on which rain falls at Cairo varies from 12 to 15, and is less in Upper Egypt, but the state of the atmosphere is best shown by the hygrometer, as on the Nile the difference between the wet and dry bulbs sometimes amounts to 24° F. and the annual relative humidity percentage is 58·46.

The best proof of the dryness of the desert atmosphere is to be seen in the state of the mummies, which there remain unchanged for centuries, though their removal to a moister atmosphere, such as that of Alexandria, causes their immediate decomposition.

Second, its purity. Prince Zagiell[1] has shown that while atmospheric air contains as a rule 4 parts of carbonic acid in 10,000 parts, the air of the desert contains no trace of this gas. Moreover, putrefaction appears checked, and meat, when exposed to the open air, becomes, after three weeks, dry and completely mummified, without any sign of decomposition. Zagiell has also noted that vegetable fermentation does not take place, and ripe fruits when left on the trees dry up without becoming rotten. This aseptic quality of the air is further demonstrated by the rapid healing of wounds and ulcerations to which the surgeons bear testimony, and also by the fact that phthisis appears to be unknown among the tribes of the desert, though cases are to be found in Cairo, where the evil influences of a great city prevail.

Third, the difference between night and day temperatures due to the effect of radiation. This has been noted by Dr. Marcet[2] even in winter to amount to between 17° and 18° F. There appears to be two seasons, one comparatively hot, and one comparatively cool, but in both the effects of radiation show themselves. The winter, consisting of November, December, January, and February, gives a mean of 58°·3 F., the summer average being 76°·1 F. The maximum of five years' observations at the Khedivial Observatory in a suburb of Cairo was 111° F.,[3] occurring July 13, 1888, and on a night of January, 1887, the minimum of 35° F. was reached.

Prince Zagiell's observations, taken every two hours in the twenty-four, show the maximum to be attained between 2 and 3 P.M., and to vary in winter between 79°·2 F. and 83°·7 F., while the minimum is reached between 3 and 4 A.M., and varies from 38°·7 F. to 39°·9 F., a range of 45 degrees. Snow is quite unknown, though ice has been noticed at night on extremely rare occasions.

In Middle and Upper Egypt, during summer, the sand becomes so intensely heated during the daytime, that although the radiation is great at night, the air remains warm from the direct action of the emitted heat, and this is especially the case with reference to the layer of atmosphere over the soil.[4] During that season in Middle Egypt the temperature rises by day from 96°·5 F. to 104° F. and falls regularly at night from 86° F. to 72°·5 F., while in Upper Egypt the temperature in the daytime ranges from 95° F. to 113° F. and falls at night from 90°·5 F. to 65°·7 F.

The winds which generally prevail in Egypt are from the north, and enable the dahabeahs and other sailing vessels to ascend the Nile against its strong current. These winds are cool and refreshing; but there is one, the Khamseen, which possesses the very opposite qualities, and is very pernicious to animal and vegetable life.

The Khamseen blows from the south or south-east, the more easterly variety being the most disagreeable.[5] It generally lasts three days, but may extend to seven. This wind is of rare occurrence, the number of days being only from four to twenty in the year. The sky is clouded by fine sand held in suspension and rendering the atmosphere grey in colour and obscuring the sun's rays, so that the appearance is like that of a London fog. But the air is hot and dry, and when the wind veers round to the north a fall of sometimes 30° F. takes place. The Khamseen shrivels up roses and other flowers, and will even warp and crack unseasoned wood. The effect on human beings is to cause listlessness and languor, not only in Europeans, but in

[1] See Marcet, *Southern and Swiss Health Resorts*, p. 207.
[2] *Quarterly Journal of Meteorological Science*, October 1885.
[3] F. M. Sandwith, *Egypt as a Winter Resort*, p. 24.
[4] Marcet, *Southern and Swiss Health Resorts*, p. 207.
[5] Sandwith, *Egypt as a Health Resort*.

the natives, who are seen lying about unfit for their work. It has not been proved to be harmful, but rather the reverse, to phthisical and bronchitic patients, but the rapid fall of temperature which succeeds has to be carefully guarded against.

The climate of the desert, as will be seen, is warm and very dry and aseptic, and as such has proved of great benefit in the treatment of phthisis and scrofula.

The writer's statistics show that out of 20 consumptives who spent 26 winters in Egypt, no less than 65 per cent. improvéd, 25 per cent. remained stationary, while only 10 per cent. deteriorated. Dry pleurisy, bronchitis, and spasmodic asthma, especially if combined with emphysema, benefit largely by a winter in Egypt, and chronic rheumatism is wonderfully alleviated.

Ophthalmia and other eye affections prevail largely in this country, and are in part attributed to the climate and soil. A large class of nerve affections are greatly benefited by a winter's residence in Egypt, and specially by life in a dahabeah.

The climates of *Algeria* and *Morocco* deserve a passing notice, because, though in close proximity to the Great Sahara Desert, they differ greatly from the climate of the Egyptian desert; and, again, though they form the southern shore of the Mediterranean, their meteorology presents a great contrast to that of the northern shore.

The French province of Algeria is a strip of country about 1,200 miles from east to west, and 200 miles from north to south, extending into the Great Sahara Desert, being situate between 32° and 37° north latitude.

The mountain ranges of the Great, Middle, and Lesser Atlas traverse the province from east to west, and form three chains more or less parallel to each other. The Lesser Atlas skirts the Mediterranean at a distance varying from 1 to 15 miles, and is separated from the Middle Atlas by the fertile valley of the Cheliff, and the Middle Atlas is again divided from the chain of the Great Atlas by the Algerian desert, an elevated plain containing salt water lakes, with an altitude of several thousand feet. Beyond the Great Atlas lies the Sahara Desert, which, according to Dr. Bennet, is the key to the Algerian climate, and converts, what would be a dry, into a moist clime.

The atmosphere which overlies this immense rainless tract of desert, becoming heated both in winter and summer, must rise into the higher strata, and thus form a vacuum, which the cooler and heavier air of the Mediterranean basin rushes down to fill. The latter is sucked in over the summits of the Atlas ranges, consequently in Algeria the regular winds are, and must be, either north-east or north-west winds, and south winds can, and only do, blow exceptionally.

These northerly winds, coming from the Mediterranean Sea or the Atlantic Ocean, are moist winds, and when they come into contact with the Atlas mountains are at once cooled and deposit their moisture in copious and frequent rain over the entire Algerian or Atlas region, and extend into the desert itself, 250 miles from the sea. Consequently the rainfall at Algiers is heavy, about 32 inches, distributed over 87 days, occurring chiefly in winter. The year is divided into two seasons, the hot and the rainy, the former extending from April to November, and the latter from November to April, the largest rainfall and the greatest number of rainy days occurring in November, December, and January. In the summer the rain often falls for several months, and occasionally seasons of drought have occurred even in winter. Such dry seasons are generally accompanied by a plague of locusts, which invade Algeria from the desert, penetrating the Atlas through

the passes and roads constructed by man, and devastating the fertile valleys of the Cheliff and destroying whole crops of cereals.

The rainfall of Algeria increases on proceeding eastward. Of the three provinces into which the country is divided, Oran, the most westerly, has the least rainfall. Constantine, the easternmost, has the greatest; while in Algiers, the central one, the rainfall is double that of Oran, and about half that of Constantine. This has been accounted for by the distribution of forests, which are extensive in the province of Constantine, less so in that of Algiers, and have all but disappeared in Oran.

Most of the winds, as has been stated, are northerly and westerly, but the Scirocco or S.E. wind, here a blast from the desert, occasionally prevails, and is injurious to man and destructive to vegetation. It occurs for the most part between June and October, and is accompanied by great heat. The mean annual temperature of Algiers is 62° F. (Scoresby-Jackson), the temperature of the three winter months being 56° F. (Pietra Santa), and that of the rainy season 62° F. The difference between winter and spring mean temperature is small. It will be seen that the climate differs from the climate of Egypt, being far moister and, rather cooler, and with regard to the first feature, it presents a contrast to its neighbour, the south-eastern corner of Spain, which is often arid and burnt up from drought, as if the rainfall of this region had been diverted to Algeria in the manner described by Dr. Bennet.

The climate of Algeria is milder and moister than that of the Riviera, and occupies an intermediate place between the latter and that of Tangiers in Morocco, where the equalising influence of the Atlantic is more felt in moderating extremes; but the great advantage which Algeria possesses over Egypt and the Riviera lies in the number and variety of sanitaria it offers to invalids. Algiers with its suburbs offers them shelter and saline breezes, while Blidah, Milianeh, and Medéah are excellent mountain stations, and the desert air and climate can be tried at Biskra in the Sahara, now connected to Algiers by railway.

In Algeria we can witness, too, the life of the nomad Arabs, who dwell in tents and move their houses and flocks according to the season, preferring the plains in winter and the mountains in summer. Among this race phthisis and scrofula are unknown; but when a number of them were imprisoned by the French Government, fifty per cent. died of phthisis.

The Algerian climate has been found of great value in the treatment of consumption, and the writer has recorded some remarkable cases of arrest under its influence.

Temperate Climates, comprising the Regions between 35° and 50° Latitude

This division includes Central and Southern Europe with its islands, the part of Asia between the Mediterranean, Black Sea, and Japan, a great part of North America and South America, south of Uruguay, besides the Colony of Victoria in Australia, New Zealand and Tasmania, and numerous isles.

The mean temperature varies from 50° F. to 60° F., a figure made up of considerable extremes. The rainfall also varies in amount, being dependent on the proximity to the sea or mountain ranges. The four seasons are well marked, but the length of each varies considerably accordingly to latitude. This group of climates must be regarded as by no means uniform in its features, the climate of each region approximating in meteorology to either the warm or cold groups between which it is placed, according to the nearness of either. The vast inland tracts of Central Asia and British North America

possess a very different climate from the Genoese Riviera and the Atlantic coast of the Spanish Peninsula.

The inland climates of Central Europe, Asia, and North America are characterised by extremes of temperature, as is shown in the Canadian winter and summer, and by dryness; whereas in the countries fringing the sea like the Atlantic portions of France, and Spain, and Portugal, these extremes are greatly reduced, and the rainfall is larger.

The temperate climates are inhabited by the most vigorous races physically and intellectually, and would seem to have been in all ages specially favourable to the growth and development of human vigour and intellect, as shown by the example of Greece and Rome.

Among the varieties of temperate climates is to be named that of the shores of the Mediterranean Sea, as, owing to the shelter from northerly winds afforded by the mountain ranges to the north of it, and the equalising influence of this warm body of water, which is neither cooled by glacier streams nor polar currents, and which undergoes considerable heating from its latitude, the north shore, and especially the Genoese Riviera, enjoys a very favourable climate, in which both extremes are considerably tempered. This is most marked in the different islands of the Mediterranean, such as, among others, Malta, Sicily, Sardinia, Corsica, Crete, Cyprus, and the Balearic Isles. The summers are somewhat hot, but the extremes are considerably modified by this inland sea.

The winter climate of the Riviera is warmer than that of the British Isles, by at least 3° F. It is dry and stimulating, with an average rainfall of thirty-one inches,[1] and the average number of rainy days is sixty-five. The winter and spring months are comparatively dry, and the principal rainfall is in September, October, and November. It exercises a highly beneficial effect on many forms of chronic disease, chiefly by its stimulating influence, and in the treatment of phthisis has been proved to be of the greatest utility.

The statistics of the hospitals of this region show that chronic degenerative disease is rare, while acute disease is common, and it is possible that this is the key to the successful treatment of chronic disease in this region, for it is found that whereas cases of chronic bronchitis, phthisis, rheumatism, and kidney disease, improve steadily under the stimulating influence, various kinds of inflammations, such as gastritis and enteritis, and affections of the nervous system, especially hysteria and insomnia, are rendered worse instead of better. Pyrexia is generally augmented, and typhoid fever is reported to run a more protracted course than in the North of Europe.

Prevalent Diseases

These are for the most part the ordinary diseases described in European and American text-books of medicine, and it will be unnecessary to recapitulate them, unless there be any which can be fairly attributed to the influence of climate.

Rheumatism, both acute and chronic pneumonia, croupous and catarrhal, and various affections of the air-passages and lungs, prevail largely in temperate climates, and may be fairly attributed to the vicissitudes of the weather, especially during the winter months, as during the summer there is marked diminution in the mortality from these causes. On the other hand, hay fever, a disease limited to temperate climates, prevails only in summer, owing to the presence in the air of the pollen of various flowering plants, which enter and irritate the nasal passages, the conjunctivæ of the eyes, and the larynx, pharynx, and lungs, the active symptoms disappearing on the

[1] Symons, *Quarterly Journal of the Royal Meteorological Society*, January 1890.

removal of the sufferer to the seaside, or at the close of the pollen season. This troublesome, though not dangerous complaint, prevails in Europe and North America during the summer months, and disappears in autumn.

The large group of exanthemata, and other fevers that prevail in temperate climates, are due to the action of organisms, and therefore cannot be attributed to climate, except in a secondary sense, as fostering their growth. In the same way such diseases as goitre and cretinism are attributable to local causes, these being the special conformation of valleys, peculiarities of soil, or certain mineral salts present in drinking water, or again individual predisposition. These diseases cannot be assigned to general climatic influences, more especially as they are found to prevail under such opposite conditions of temperature as the Soudan in Africa and British North America, and also both in dry and in moist climates.

Many diseases, like leprosy and pellagra, have been referred to peculiarities of diet, which has been proved in the case of pellagra in Italy, but is not yet substantiated with regard to leprosy; but this latter disease, prevailing as it does under the most varying conditions of climate, must be considered entirely independent of this factor.

Pulmonary consumption cannot be said to be the special production of severe climate, though doubtless immunity from the disease has been shown to exist under various and indeed opposite climatic conditions.

Cold Climates

This division embraces a large area, from 50° N. latitude to the poles, a great portion of which is ocean, or else, as is the case with the southern pole, unknown regions. The habitable portions are in the northern hemisphere and include the North of Scotland, Denmark, Sweden and Norway, Iceland, Finland and Lapland, Northern Russia, with Spitzbergen and Nova Zembla, Siberia and Kamschatka, and in America, part of British North America and Greenland. This group has been subdivided into a cold region, with a mean temperature between 50° and 32° F., and a glacial region with a mean below the freezing point.

The temperature falls rapidly between latitudes 55° and 75°, and the fall amounts to 22° F. to 27° F., the coldest region being not at the pole, but about 10° from it north of Behring's Straits, the mean temperature there ranging between 17° F. and 19° F.

As is well known, in the more northerly portion the sun never rises above the horizon for several months in the winter, when the sky is illuminated by the aurora borealis, and in the summer for several months the sun never sets. During this season, June and July, the temperature rapidly rises to 55° F., to 60° F., to 80° F., or even 90° F., and rapid development of the vegetation and growth takes place, but at the end of July fogs and rain appear and are soon succeeded by snow and frost, and the long winter again recommences, during which there is scarcely any diurnal variation of temperature. The winds seem chiefly N.E. and S.W., and their rapid changes give rise to tempests. The rainfall, generally in the form of snow, only amounts to a few inches. This description does not apply to the whole of the cold region, but to the northern part of it, whereas the portion abutting on the temperate zone partakes of that climate. The inhabitants of cold regions are, as a rule, a vigorous race, possibly from the severe battle of life they must fight to maintain existence, and their diseases may be generally traced to either defects in their dietary or their overcrowding in small and ill-ventilated huts. Scurvy and scrofula are the principal diseases, the former arising from a deficient supply of vegetables and fruit,

and the latter from the overcrowding and want of a proper supply of food generally. Ophthalmia and amaurosis are also reported to be present, from the reflection of light from the snow in the polar regions. As physicians, we have little to do with this class of climates, but we must not forget that dry cold, which is the feature of this group, has a bracing effect on the human system, improves the appetite, promotes the performance of a large amount of muscular work, and, as it is fatal to all germs, is a good antiseptic.

Marine Climates

are characterised chiefly by marine influence, and especially by the presence of warm sea currents, the regions included being capes, islands, peninsulas, and promontories washed by the ocean or salt seas, which by their warmth and equalising influence raise the mean temperature of the adjacent regions, and at the same time temper the extremes. The source of heat being a moist one, the humidity and rainfall are increased, and add a certain soft-

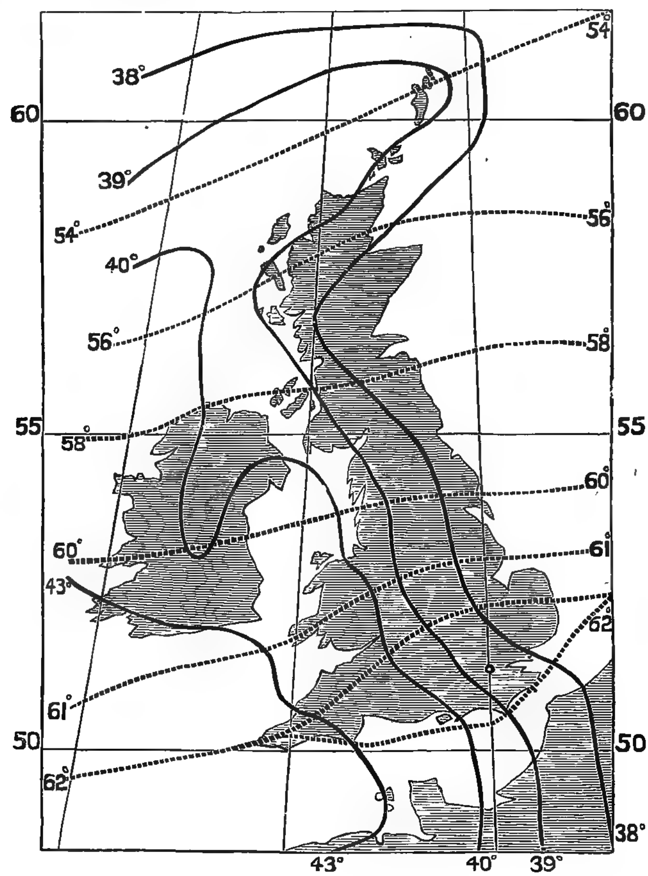

Fig. 81.

ness to the atmosphere. Such is the climate of Great Britain and Ireland, the coasts of Norway and Iceland, which all, from their relation to the equatorial current and Gulf Stream, enjoy a far milder, though moister, climate than they would experience if situated at the same latitude in the centre of Asia or of North America.

The British climate may be taken as the type of this class, as it certainly

owes its mild atmosphere to the sea encompassing our islands, and to the warm equatorial current and the winds generated by it. This is shown in several remarkable ways. First, the winter temperatures of the towns on the south coast are higher than inland places at no great distance from them (Tripe). Second, the mean winter temperature of these stations decreases towards the east of the British Channel, the mean winter temperature of Hastings being 5° F. less than that of Torquay. Third, the effect on the winter isothermal lines of Great Britain (see woodcut). In August the isotherms (dotted lines) very much follow the lines of latitude, the east coast of England being slightly warmer than the western coasts of England and Ireland, but in January the isotherms (continuous black lines) become almost vertical, the isotherm of 39° F. running through Shetland and the islands off the west coast of Scotland to Hastings, while that of 40° F. passes through the Isle of Man, Llandudno, and Portsmouth. The isotherm of 43° F. runs through the extreme south-west of Ireland, through Devonshire and the Channel Islands. Thus the power of the sun being weakened in winter, the influence of the equatorial current is more sharply shown, and we see what a valuable warming agent it proves to us in winter. Fourth, in the increase in the rainfall. This is much greater on the western coasts of England and Scotland, which are strongly under the influence of the equatorial current, than on the east coast, which is less so. The rainfall of the west coast varies from 60 to 80 inches, and that of the east coast is 20 inches, and on the east coast the extremes of temperature are also more marked. The characteristics of the British climate are absence of extremes, great humidity, and great variability and absence of sunshine. The result is to be seen in a vigorous race, liable to various diseases arising partly from vicissitudes of climate themselves, and partly from confinement within doors which these, to some extent, render necessary. The good complexions of the British, and especially of the women, are due to the protection from sunburning which the moist vaporous atmosphere affords.

The principal diseases due to climate are those affecting the lungs and air-passages—such as asthma, bronchitis, pharyngitis, laryngitis, pleurisy, pneumonia and phthisis, rheumatism and its sequelæ, and various forms of kidney disease; the greater part of which may be attributed to the dampness of the climate and the constant changes in the weather.

Rheumatism and bronchitis prevail most in the winter months, and, according to Scoresby-Jackson, a low mean temperature during the winter months gives rise to an increase in the death-rate from phthisis and bronchitis, and this relationship is more clearly to be observed if the low temperature be sustained for some months without intermission.

Phthisis prevails all the year round in England, and it has been demonstrated to bear a distinct relationship to dampness and impermeability of soil, its connection with particular districts depending apparently more on this feature than on the meteorology, though the great variability of this latter exercises some influence.

In the last forty years the death-rate from phthisis in the United Kingdom has diminished to half, principally from the more efficient soil drainage and the various measures enforced by the Legislature to improve the health of the working classes.

Nevertheless, the fact of the great prevalence in Great Britain and Ireland, and its rarity in many dry countries, points to some favouring influence to the development of phthisis in the climate of this part of the world which must be partly ascribed to its elements of damp and frequent change. With

reference to the treatment of phthisis, the writer's statistics[1] of 243 patients treated at the various health resorts on the south coast showed conclusively that the more easterly the station the greater the amount of local and general improvement to be derived, and that, for instance, Hastings gave far better results than Torquay or Penzance, and that Bournemouth and Ventnor occupied a position intermediate between these in improvement of patients.

Sea Voyages

The subject of the climate of the sea falls naturally under the heading of Marine Climate, and we here propose briefly to consider the question of *sea voyages* in their relation to health. Rattray's[2] important observations on the crews of various ships of the Royal Navy during voyages in different climates, show that life at sea is by no means an unmixed blessing, and that the tropics should be avoided by the natives of colder and temperate climates, especially by the young, as also by weakly patients or those suffering from chronic disease. Rattray also shows that healthy adults should not remain too long in tropical climates, and should leave them at once if strength and flesh begin to fail; and that the avoidance of other weakening influences, such as a faulty diet, over-fatigue, and impure air, which are not uncommon concomitants of a seaman's life in the tropics, is absolutely necessary to preserve health. The most striking result of Rattray's observations was the loss of weight by able-bodied seamen under the combination of the tropics and salt diet, which occurred in 81·55 per cent., each losing, on an average, 4 lbs. When muscular exertion was added, the percentage of losers exceeded 91 per cent., who, in 104 days, lost, on an average, 7 lbs., the ship boys not losing so much as the men. Rattray also comments on the wonderful improvement always noted when the crews reached temperate climates, so that he sums up with the conclusion that, to preserve health, a tropical climate should be frequently changed for the more temperate ones of the higher altitudes or latitudes.

Rattray's careful observations on the crews show that in the tropics the urine decreases from $59\frac{1}{2}$ per cent. to 42 per cent., and that the perspiration increases from $8\frac{1}{2}$ per cent. to 30 per cent. There was a diminution of $4\frac{1}{2}$ per cent. in the fluid exhaled by the lungs, and a slight increase in that secreted from the bowels. The kidneys appeared to be the principal eliminators of surplus water, both in the tropics and in temperate climates, but the skin was most worked in the tropics and the lungs in the temperate climes.

It is evident, then, that for sea voyages to be profitable, a long sojourn in the tropics must be avoided; and this has greater bearing on invalids than on healthy people. The writer's[3] statistics of a number of consumptives who took sea voyages to the Cape and Australia were very favourable, but it should be stated that by far the larger proportion of these patients (72 per cent) were in the stage of lung tuberculisation, and but few had cavities. In 28 per cent. both lungs were affected; 89 per cent. of these patients improved; $5\frac{1}{2}$ per cent. remained stationary, and $5\frac{1}{2}$ per cent. deteriorated. Most of these patients undertook the voyage to Australia round the Cape of Good Hope in clipper ships, not steamers, and returned either by the same route or by Cape Horn. Some years ago, being anxious to ascertain the exact climatic conditions of voyages, with the help of his friend, Captain Toynbee, of the Meteorological Office, the writer consulted

[1] *Lettsonian Lectures.* [2] *Proceedings of Royal Society*, 1869–72.
[3] *Influence of Climate on Consumption*, p. 99.

the logs of the various sailing vessels bound to Australia or New Zealand, at different times of the year, and extracted such portions of their meteorology as seemed likely to prove useful to invalids.

When a ship leaves England in October, the temperature ranges from 52° F. to 58° F. for the first five days. Off the Azores it rises to 60° F., and on passing the Canaries it reaches 70° F. On the vessel crossing the equator the maximum 80° F. is attained, but this is greatly tempered by breezes, as a rule. Afterwards the temperature gradually falls, and in 39 S. latitude 70° F. is the average, and this sinks to 60° F. on reaching the Cape of Good Hope.

After rounding the Cape, the temperature, owing to the mixture of the warm Agulhas current, with cold currents from the Antarctic Circle, becomes uncertain, and varies from 49°·5 F. to 60° F., the currents overlapping each other and causing much variation of temperature in the superincumbent atmosphere. The vessel reaches 45° S. latitude and steers eastwards, the thermometer ranging between 40° F. and 50° F., owing to the nearness of the Antarctic Circle. When 70 E. longitude is attained, the temperature remains steadily above 50° F., and rises to 66° F. on approaching the continent of Australia. Throughout the voyage the temperature may be said to vary between 40° F. and 80° F. The number of rainy days is about twenty. The atmosphere is a moist one; the hygrometer gives an average of 2° F. to 5° F. difference between the bulbs, which, considering the high temperature of some portion of the route, shows considerable humidity. The voyage, when commenced in May and ended in August, does not differ very much in temperature from that commenced in October. The temperature of the equator, then, is 85° F., but the other records are much the same, only the traveller has the disadvantage of landing in Australia in mid-winter. The return voyage from Australia or New Zealand to England is seldom by the Cape of Good Hope, but usually round Cape Horn, and consequently the vessel's course is further southward, and approaches more closely to the Antarctic Circle. It is here that low temperatures are met with, and the thermometer, which was 55° F. off New Zealand (Wellington) in April, fell to below 40° F., and for 28 days the temperature ranged between a few degrees below 40° F. and a few degrees above it, with a south wind from the Antarctic regions. However, in 40° S. latitude, a rise to 50° F. takes place, and off Monte Video it is 70° F. and 80° F. at the equator, and England is reached the middle of July.

The Australian or New Zealand voyage occupies about three months in a clipper, or from 37 to 45 days in a steamer, the former being preferable for health purposes. According to Dr. Maclaren, the first influence of the outward voyage on the invalid is a sedative one, but on approaching the Cape, the cooling atmosphere and the fresh breezes exercise a tonic effect, and improvement of appetite and gain of weight take place. A shortened edition of this voyage is the one to the Cape of Good Hope, occupying about three weeks in a steamer; it is a good method of escaping part of the British winter, as, with a halt at Cape Town or Wynberg, it occupies about two months.

Other winter voyages which can be recommended are those to the West Indies by the Royal Mail Steam Packet Company's steamers, which touch at most of the islands and several of the ports of Central America, the trip occupying from six weeks to four months, spent mostly in mild regions; but it is doubtful whether Rattray's objections to long sojourns in the tropics do not apply here, and this voyage would not be advisable for the young.

Another salutary trip is the Brazilian voyage, where the vessel touches at Lisbon, Teneriffe, Pernambuco, Bahia, Rio de Janeiro, Monte Video and

Buenos Ayres, and occupies two to three months. Here temperate climes are intermingled with the tropics much to the traveller's benefit.

Far different in its meteorology and in its results on invalids is the voyage to India and China, through the Suez Canal and Red Sea, for here we get sudden transitions from extremes of temperature, which are most pernicious. The increased heat in the Suez Canal and the still greater rise in the Red Sea, where the thermometer often marks 98° F., combined with great dryness, the wet and dry bulbs showing a difference varying from 8° to 12° F., acts most injuriously on the appetite and strength and flesh of patients, and the temperature of the climate of the Indian Ocean (79° to 81° F.) is too high to promote health. On the return voyage, too, the passing from the hot atmosphere of the Red Sea into the cooler Mediterranean climate, especially if the Tramontana be blowing, checks perspiration and often induces temporary albuminuria.[1] The writer has, moreover, known more than one consumptive perish in the Red Sea from the overpowering influence of heat, inducing diarrhœa; and the depressing effect on constitutions already weakened by disease is most disastrous.

Sea voyages, if the right season and route be chosen, are productive of much good, as they are a means of supplying patients with abundant fresh air without fatigue, and the atmosphere is rich in ozone and free from dust and germs. As long as the weather is fine and the invalid lives, and even sleeps, on deck, all is well, but when bad weather confines him to his cabin, a very different state of affairs prevails, for he may be doomed to imprisonment in what in his own house he would designate a cupboard, and which, when the portholes are closed, as during storms, often proves a very ill-ventilated one. Also the lack of proper exercise, except walking the deck, and occasionally the chance of running short of provisions, are serious drawbacks.

Sea voyages have proved most useful in checking the tendency to hæmorrhage, in promoting sleep, and are, therefore, very beneficial where the brain and nervous system have been overworked, and in checking chronic discharges, such as from fistula, strumous abscesses, and old ulcers, and in assisting antiseptic treatment. The appetite is greatly stimulated on board ship, and, as a rule, the larder is well supplied, and consequently food is consumed in abundance, and large gain of weight, often amounting to one or two stone, follows. Sometimes too great indulgence is given to the appetite, and this excess, combined with want of exercise, promotes biliousness and dyspepsia, which are by no means rare on board ship. Often another bad practice springs up on board—viz. drinking, in most cases pursued through want of occupation, and this often ruins the prospects of an otherwise promising patient.

Mountain Climates

This division is characterised by diminished barometric pressure, increased diathermancy, and by great extremes of temperature. So many of the leading features of these climates have been alluded to already, that it will not be necessary to treat of them as fully as has been done in the case of the other four groups, but we must say a word on some of their striking qualities. In addition to being distinguished by rarefaction and diathermancy of atmosphere, they are strongly aseptic, and this is shown by the long period that meat keeps in the mountains before undergoing decomposition. They are

[1] An intelligent surgeon in the service of the Peninsular and Oriental Company informed me that, on testing the urine of the healthy passengers after entering the Mediterranean from the Canal, he found albumen in all.

also very dry, especially during the winter months, though this is partly due to air at a low temperature being incapable of holding moisture in suspension. Absorption of atmospheric oxygen by the blood takes place more readily, while, at the same time, the carbonic acid formed within the body passes outward through the pulmonary tissue into the air, which is inhaled with a greater degree of facility than at lower altitudes (Marcet).

One of the greatest arguments in favour of mountain climates is the well-known immunity from the greater number of diseases mountaineers enjoy, and the general vigour of body that they possess. When we contrast them with lowlanders, the comparison is almost always in favour of the former, who are generally taller, with broader and deeper chests, and greater powers of endurance, especially in marching and walking; these characteristics are present in mountain races over the whole globe, be they the natives of the Himalayas, the Indians of the Andes, the chamois hunters of the Tyrol, the guides of Switzerland or the Highlanders of Scotland. The immunity from phthisis, which has been so strongly insisted on by Kuchenmeister and others, has not been found to be so complete as he has set forth, nor is there any fixed immunity altitude for each degree of latitude, as he would infer, and experience has shown that unhealthy modes of life, insufficient food, ill-ventilated dwellings, and pernicious habits will produce phthisis at any altitude or in any latitude, but that, if these are avoided, undoubtedly an altitude of 5,000 to 6,000 feet above sea-level will exercise a decidedly protective influence against phthisis, even in those predisposed to that disease. The only diseases which the mountain climates can be said to produce are the so-called 'mal des montagnes,' already described, and a form of dry pleurisy, known in the Alps as Alpenstick; but while they largely benefit phthisis and other strumous affections, they are injurious and consequently contra-indicated in the following: (1) emphysema; (2) chronic bronchitis and bronchiectasis; (3) diseases of the heart and great vessels, of the kidneys, and of the liver; (4) diseases of the brain and spinal cord, and all states of hyper-sensibility of the nervous system; (5) the catarrhal and laryngeal varieties of phthisis, as well as erethric phthisis, when there is great irritability of the nervous system, and all cases of advanced disease of any kind.

On the other hand, the benefit of mountain climates is immense in the following: (1) cases of strong hereditary predisposition in which phthisis is either threatened or is in a state of early development; (2) imperfect thoracic or pulmonary development; (3) hæmorrhagic phthisis; (4) chronic tubercular phthisis in its various stages, provided the lung-surface be not too largely involved to admit of proper aëration at high altitudes, and there be no pyrexia; (5) chronic pleurisy, where the lung does not expand after the removal or absorption of the fluid, and chronic pneumonia, without bronchiectasis, that does not resolve; (6) anæmia; (7) and spasmodic asthma without any considerable amount of emphysema.

Another point to bear in mind is, that no patient should attempt high altitude climates who cannot take exercise, and abundant exercise, and therefore the aged and very feeble are clearly debarred.

Though among the mountain ranges of the globe we have plenty of choice of elevation, the number of stations suitable in the way of height, shelter, latitude, and accommodation is limited, and they are the following:

1. The Alpine, varying in height from 4,771 feet to 6,000 feet, with a winter mean temperature of about 28·1° F., great extremes of climate, and fifty-two rainy or snowy days; the principal stations being St. Moritz (6,090 feet), Davos (5,200 feet), Maloja (5,941 feet), Wiesen (4,770 feet), and Andermatt (4,738 feet), in Switzerland. The winter climate is very cold,

dry, and calm, but the sun's rays are most powerful, as shown by the tanning of the skin.

2. The Rocky Mountains sanitaria of North America, varying in altitude from 5,200 to 9,000 feet, the climate resembling that of the Alpine resorts, but warmer, drier, and with less snow, but more dust. The stations in Colorado are Denver (5,200 feet), Colorado Springs (6,000 feet), Manitou Springs (6,370 feet) Poncha Springs (9,000 feet), Waggon Wheel Gap (9,000 feet), Elkhorn (7,500 feet), Palmer Lake (7,238 feet), Yellowstone National Park (6,000 feet), and Santa Fé (7,013 feet), Silver City (5,890 feet), and Mesilla Valley (4,000 to 7,000 feet), in New Mexico.

3. The sanitaria of the Andes, of altitudes varying from 8,000 to 13,500 feet, and owing to more southern latitude enjoying warmer and more equable climates than the above and in many cases a mean temperature of 60° F. at all seasons: Santa Fé di Bogota (9,000 feet), in New Granada; Quito (10,000 feet), Equador; Jauja (18,000 feet), Tarma (10,028 feet), and Huancayo (10,718 feet), in Peru; La Paz (13,500 feet), in Bolivia. Climate generally dry, warm, and bracing, except at La Paz, where the winter is cold.

4. Himalaya and other mountain stations, of altitudes varying from 3,600 feet to 8,000 feet. Himalayan 4,000 feet to 8,000 feet. Rainfall 70 to 132 inches. Mean temperature 60° to 70° F. Darjeeling, Simla, Landour, and Nynee Tal, Nilghiri sanitaria, with an altitude of from 5,000 to 7,000 feet, mean temperature from 54° to 70° F., and rainfall from 50 to 60 inches. The climate is cool, but subject to considerable extremes, and damp owing to the excessive rainfall.

5. The South African Highlands of Cape Colony, Orange Free State, and Transvaal, containing various stations of altitudes from 4,000 to 6,000 feet. Taking Bloemfontein as a type, the climate is warm, with seldom any extreme of cold even in winter, and delicate persons sleep in the open all the year round, except during the rainy season and a few days of winter. The average minimum is 55° F., the average maximum for the six hot months 82° F., the humidity 55 per cent., the rainfall seventeen inches, and the number of rainy days seventy. In the Karoo districts of the Cape we have as suitable stations for invalids Aliwal North (4,348 feet), Turkestan (4,280 feet), Dordrecht (5,200 feet), and Burghersdorft (4,650 feet); in the Orange Free State, Bloemfontein (4,540 feet); and in the Transvaal, Pretoria (4,007 feet), and Johannesburg (5,000 feet). In South Africa it is not only the splendid climate which benefits the visitors, but the mode of life pursued by most of them: i.e. living on the trek in a waggon, shooting their food-supply by day, and sleeping in the open at night.

Though these groups vary considerably in climate as regards temperature and moisture, they all agree in the reduction of the barometric pressure, and this is the essential feature of the whole series, and the use of them in the treatment of different forms of chronic disease has produced most astonishing and beneficial results, which will probably increase as the number of high altitude sanitaria are multiplied. In the treatment of consumption, the writer has shown from his statistics that out of 141 cases of phthisis thus treated 74·82 per cent. improved, and among these arrest of the disease took place in 44 per cent., and deterioration in only $21\frac{1}{2}$ per cent.

The statistics of Dr. Hermann Weber and Dr. Denison (of Colorado) confirm this conclusion.

WATER

BY

THOMAS STEVENSON, M.D., AND F.R.C.P. (LOND.)

WATER

WATER is one of the prime necessaries of life, and ranks next to air in the influence which it exercises upon the processes of animal life. Some physicians would, indeed, contend that morbific influences are more often conveyed through the instrumentality of water than by the atmosphere. An adequate knowledge of the properties of water in its various physical states of solid, liquid, and vapour, and especially of its solvent action on gases and on saline bodies, is all-important to the health officer; to whom also the impurities present in natural water-supplies are matters of the greatest practical interest. Our existing knowledge of the effects of these impurities upon human beings is considerable, though still very imperfect; but the means at our disposal for detecting, quantitatively estimating, and appraising at their proper value such impurities, in spite of the numerous and extended published researches of chemists and biologists, are comparatively limited. Yet when we contrast the knowledge which we possess, in this respect, of water with that of the atmosphere and the soil, it may safely be asserted that we have as complete information respecting the composition and properties of the constituents of our domestic water-supplies as we have of the air we breathe, and of the soil on which we dwell. We may soon expect, moreover, to be in the possession of fuller knowledge of the bacteriology of water-supplies—a branch of science inseparably associated with the bacteriology of the atmosphere and the soil. From the study of the minute organisms habitually and occasionally present in air, water, and soil, it may be expected that great advances in sanitary science will accrue.

To the chemist, water, long believed to be an element or simple substance, is now known to be a compound of oxygen and hydrogen, in the proportions of eight parts by weight of oxygen to one part of hydrogen. Below 0° C. (32° F.) it forms a solid body (ice); above 100° C. (212° F.), under the ordinary barometric pressure of 30 inches, or 760 millimetres nearly, it exists as a gas (steam); whilst at all intermediate temperatures it forms the liquid, water, *par excellence*. During its passage from the liquid to the solid state—i.e. during the act of freezing, at 32° F.—water suddenly expands to the extent of $8\frac{1}{3}$ per cent. of its liquid volume, so that ice at its melting point is specifically lighter than water at the same temperature (water at its freezing point), floats upon it, and has the specific gravity 0·9168 when compared with water at the same temperature. Water in freezing gives off a large amount of heat, which is again absorbed or becomes 'latent' during the subsequent liquefaction of ice; and these absorptions and emissions of heat during thawing and freezing play a great part in tempering the severities of climate, and in preventing the otherwise sudden destructive changes in the temperature of the atmosphere which would otherwise ensue.

Another important physical property of water is its anomalous expansion whilst undergoing changes of temperature. Water whilst passing from its freezing to its boiling temperature at first contracts until the temperature of 4° C. (39°·2 Fahr.) is reached; and this is the temperature at which the

liquid attains its maximum density. Above 4° C., it expands with rise of temperature until its boiling point is reached. The important bearing of this anomalous expansion is, that when a mass of water—*e.g.* that in a pond—is cooled by radiation at its surface, the cooler surface water becomes denser than the warmer water beneath, and hence sinks until the whole mass of water is cooled down to 4° C. (39°·2 Fahr.) Radiation still going on, the surface water now cooled below 4°, no longer sinks, but being specifically lighter than the warmer water beneath remains on the surface, till, the freezing point being attained, the liquid freezes, and the solid crust of ice formed in a measure protects the water beneath from the influence of cooling currents of air. This freezing of deep masses of water at the surface, and the maintenance of the subjacent water in winter at a temperature approximating to 39° Fahr., serves to maintain the processes of animal life in the aquatic organisms met with in ponds, lakes, and reservoirs of water generally.

The disintegrating action of water upon rocks and soils is largely due to the irresistible expansive force exerted by water during its solidification; for in this process, as has been already stated, water expands by about one twelfth of its bulk, and the ice formed is practically incompressible. Hence the hardest rocks are rent asunder by freezing water. A familiar instance of the force exerted by water during its solidification is seen in the bursting during a frost of the leaden pipes ordinarily used for the distribution of domestic water-supplies. Thick leaden pipes may be thus ruptured when the freezing water lies stagnant within them; and when a thaw sets in, the plug of ice which has filled in and closed the rent during the frost, liquefies, and the resulting leakage at once reveals what has happened.

Water boils at a temperature varying with the atmospheric pressure. When this is normal, i.e. equal to the pressure of a column of mercury of 30 inches, or nearly 760 millimetres in height, the boiling point is 100° C. or 212° Fahr. On the tops of mountains where the pressure is less than 30 inches of mercury the boiling point is lowered; and conversely at the bottom of deep mines the boiling point is appreciably higher than 100° C.

At all temperatures above its boiling point water forms a transparent, colourless, invisible gas. In passing from the liquid to the gaseous state, it absorbs a large amount of heat without becoming hotter (latent heat of vaporisation); and it is this absorption of heat which causes the cooling effect of the evaporation of surface water to exert an important influence in meteorology and in the modification of climate. The great specific heat of water as compared with other liquids—i.e. the relatively large amount of heat required to change its temperature—has also a most beneficent effect in preventing sudden changes of temperature.

Water evaporates at all temperatures, and the evaporation of solid water in the form of ice and snow is an obvious and familiar phenomenon. The tension of water-vapour, or its tendency to evaporate at any given temperature is treated of elsewhere (see METEOROLOGY, p. 164). The relative saturation of air with aqueous vapour is termed 'humidity' of the atmosphere, and bears no direct relation to the quantity of aqueous vapour therein.

The atmosphere forms a vast storehouse or reservoir for water, where it for the most part exists in the form of invisible gas or vapour; and a never ceasing silent process of distillation is going on around us. This process, effected by the heat of the sun's rays, is unceasingly providing the surface of our globe with fresh and pure water, which again is as constantly becoming polluted by its passage over and through organically polluted soils. It is commonly stated that the atmosphere contains a variable amount of aqueous vapour 'dissolved' in it; but it would perhaps be more correct to say that the

atmosphere is a variable mixture of the gases, oxygen, nitrogen, carbon dioxide, and water. When such a gaseous mixture is cooled, its capacity to retain water in the gaseous state is diminished, and droplets of liquid water are deposited on cold solid bodies in the form of dew. In other words, the vapour-tension of water rises with increase of temperature.

In the British Isles the amount of aqueous vapour in the atmosphere ranges from two grains per cubic foot of air in winter to twelve grains in summer, or from one third per cent. to two per cent. by weight. Our atmosphere is therefore, as has been already stated, a huge storehouse into which pure gaseous water evaporates under the heating influence of the sun's rays, to be again precipitated as rain, hail, or snow; and thus in the vast laboratory of nature there is provision for a constant supply of pure water. Were it not for this unceasing process of distillation, our water-supplies would speedily become so highly charged with impurities as to become unfitted for the maintenance of animal life.

Water is the most universal known solvent. It dissolves, or retains, all the known gases; and it also dissolves or takes up all known solid bodies, except perhaps the diamond and some of the noble metals. Even the most refractory minerals—commonly termed 'insoluble'—gradually yield to the solvent action of water, an action often greatly aided by the gases dissolved in all natural waters. Thus, for example, sulphate of barium or heavy spar, one of the most insoluble known chemical substances, dissolves in water to the extent of one part in four hundred thousand parts by weight, or one sixth of a grain per gallon. It is in this way that rain-water becomes charged with the gaseous constituents of the atmosphere, viz. oxygen, nitrogen, and carbon dioxide gases; and to a less extent with ammonium nitrate and other so-called solid impurities. Thus also water in flowing over and percolating through the soil takes up from this, or dissolves, additional quantities of carbonic acid, since the soil is always richer in this gas than the air above it: also the more or less soluble mineral constituents of the soil—notably the carbonates of calcium and magnesium, sulphates, chloride of sodium, and other saline matters. Thus, again, streams and rivers are the silent conduits by which the solid crust of the earth, partly dissolved and partly in a state of mechanical suspension, is carried seawards and there deposited in the form of new rocks, or retained in solution.

Absolutely pure water, in the chemical sense of the term, is a substance of extreme rarity, and has only been obtained by repeated distillations of fairly pure water in vessels constructed of silver. Water, when retained in contact with surfaces of porcelain or glass, quickly takes up small quantities of solid impurities owing to its solvent action upon the silicates of which such vessels are constructed.

In the following pages we shall have to treat of water, not in its chemically pure, but in its natural state; and in speaking of a pure water, the sanitarian means a water practically free from noxious gases, from injurious organic matters, from injurious metallic constituents, and containing no excess of mineral ingredients, albeit charged with moderate quantities of ordinary innocent saline matters, and well aërated. We shall consider the sources of our water-supplies; the collection, storage, and distribution of water; its impurities, their influence on health, and their removal; the quantity of water requisite for domestic and other purposes; the means at our disposal for determining its purity or impurity; and the constituents generally present in water. The permissible limits of the various constituents and impurities of potable water-supplies will also have to be stated, so far as existing knowledge permits us to do so.

SOURCES OF WATER-SUPPLY

The sources of water-supply are very varied; but they may be classified as follows, each class of water having its own special characteristics. All waters are, however, as has been already stated, ultimately derived from that vast mass of naturally distilled water which descends through the atmosphere in the forms of mist, dew, rain, hail, and snow. In addition there is water artificially distilled, as on ship-board and in tropical regions, approximating in its characters more to rain-water than to any other natural water.

I. *Rain-water*, which, after being collected on the roofs of buildings and other more or less flat surfaces, is stored in appropriate receptacles. This when collected, with due care, on clean surfaces in country districts, is in one sense the purest natural water. That collected in and near towns and factories is generally too impure to be fit for drinking purposes.

II. *Upland water*, or surface water, which having fallen on a sparsely populated and but little cultivated soil is collected in ponds, lakes, or artificial reservoirs, and stored for use. Such waters, as a rule, contain very little dissolved saline matter; though they may contain a good deal of dissolved peaty matter, rendering them brown in colour and bitter in taste.

III. *Spring and well-waters*. Here the rain-water has percolated to a greater or less depth into the soil and subsoil, and is by the pressure or 'head' of superjacent water in the soil forced to the surface through holes and fissures (spring-water) or into holes sunk into the earth (well-water). Spring and well-waters belong practically to the same class. They vary very greatly in their composition, according to the nature of the subsoil whence they are derived. Springs and deep wells usually afford hard, sparkling waters; whilst shallow wells commonly afford bad and organically impure waters.

IV. *Rivers* are fed by surface water, waters from land drainage, and by the overflow of springs: hence they vary greatly in composition and purity. Often they are largely contaminated by sewage. As a rule they furnish waters less hard and saline than the average of spring waters feeding them, part of the chalk of the springs having been deposited on exposure to the air, by loss of carbonic acid. When a river is large, its water generally has a pretty uniform composition, except during times of flood. This is well shown in the water of the Thames at the intake of the London water companies. This water does not materially vary in the amount and proportions of its various saline constituents at different seasons of the year. But it must be admitted that the Thames is more largely derived from springs discharging into the bed of the river than is the case with the majority of British rivers.

RAIN-WATER

Rain-water varies in composition according as it is collected in the country or in towns, but is never pure water. It invariably contains, besides the gases of the atmosphere, nitrate and nitrite of ammonium, solid amorphous and crystalline particles in suspension, and minute organisms. That of towns contains the acids generated by the combustion of coal, and notably sulphuric and hydrochloric acids. The aggregate amount of these two acids, in the free state, may reach as much as seven grains per gallon or ten parts per 100,000. Rain-water collected near the sea, and even many miles inland, contains small quantities of the salts present in sea-water. Even the rain-

water collected in Florence was found by Bechi to contain 0·28 grain per gallon, or 0·4 part per 100,000, of solid matter, about half of which was organic and half inorganic, the chief portion of the latter being sulphate of calcium and choride of sodium. ('Deutsch. Chem. Ges. Ber.' viii. p. 103.) Bechi also determined the amount of ammonia and of nitric acid in the rain-water falling respectively in Florence, and at Vallombrosa in the Apennines, more than 3,000 feet above the sea-level. At Vallombrosa the ammonia was, on the average, 0·036 grain per gallon, or 0·51 part per million; whilst in Florence there was 0·078 grain, or 1·11 part per million. In Vallombrosa the nitric acid was 0·041 grain per gallon, or 0·58 part per million, and in Florence 0·083 grain per gallon or 1·18 part per million. Lawes and Gilbert found the average aggregate amount of combined nitrogen in country rain-water, as ammonia, nitrates, and nitrites, to be nearly 0·07 grain per gallon, or one part per million.

Rain-water dissolves at the ordinary temperature of our country about 20 c.c. per litre, or 5·5 c.i. per gallon, of the atmospheric gases, of which about 7 c.c. per litre, or nearly 2 c.i. per gallon, is oxygen; 12·5 c.c. per litre, or 3·5 c.i. per gallon, is nitrogen; and 0·5 c.c. per litre, or 0·14 c.i. per gallon, is carbon dioxide gas. But rain-water is rarely, if ever, fully saturated with oxygen, this gas being in part appropriated by the organic matters present in the water; so that the oxygen rarely exceeds 1·75 c.i. per gallon or 6·3 c.c. per litre.

The following may be taken as the average composition of rain-water collected in inland districts remote from towns:—

	Grains per gall.	Parts per 100,000
Saline constituents	2·1	3·0
Combined nitrogen	0·07	0·1

The River Pollution Commissioners in their sixth report, issued in 1874, give the following as the gaseous constituents of rain-water:—

	C.i. per gall.	C.c. per litre
Nitrogen	3·63	13·08
Oxygen	1·77	6·37
Carbonic acid	0·35	1·28
Total gases	5·75	20·73

When rain-water has to be collected from buildings and stored for drinking purposes, special precautions must be taken to ensure its cleanliness and freedom from metallic compounds and from organic impurities. For this purpose it should never be collected from surfaces of lead, and even roofs covered with sheet zinc or galvanised iron communicate some zinc to the water collected on them. Roofs covered with slate afford the best collecting surfaces for rain-water. The first water collected after dry weather is always dirty, polluted with the excrement of birds, and contains vegetable spores.

Mr. Charles Gay Roberts has designed a very ingenious and effective separator (figs. 82 and 83) (p. 230) for automatically getting rid of the first and dirty rain-water falling after drought.

A vertical separator is used where a single stack pipe carries the water from the roof to the tank.

In figs. 82 and 83, the front of the vertical separator has been removed to show the interior. Fig. 82 shows it in the position that it retains when running foul water into the waste pipe during the first part of a shower, while the roof is yet dirty. Fig. 83 represents it when it has canted and has begun to run pure water into the storage tank, after the roof has become

clean. The change of position is effected by the gradual accumulation of a small portion of the water in the chamber J of the canter; when the water reaches a certain height, it makes the left side heavier than the right, and the canter turns a little on the pivot M that supports it, so that the water is delivered two inches further to the right than it was before; and whereas it at first ran through N into the waste pipe, it now runs through O into the storage tank.

In figs. 82 and 83, A A are strainers removable for washing. B is a removable slide, with two small holes to regulate the flow of sufficient water to work the canter. C is a sluice to be adjusted to the area of the roof. D is the outlet

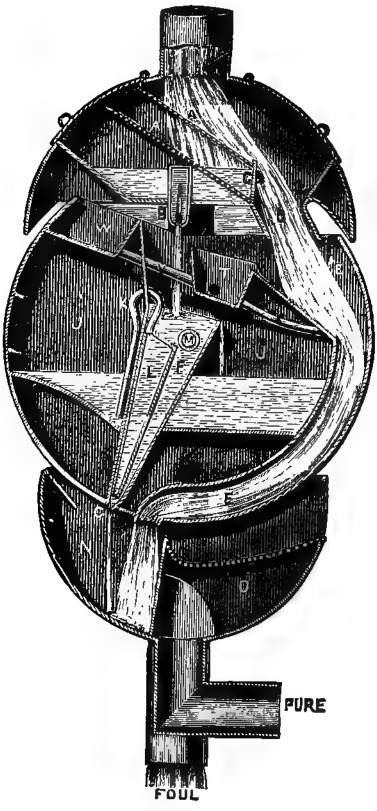

Fig. 82.—Section of vertical separator impure water passing to waste.

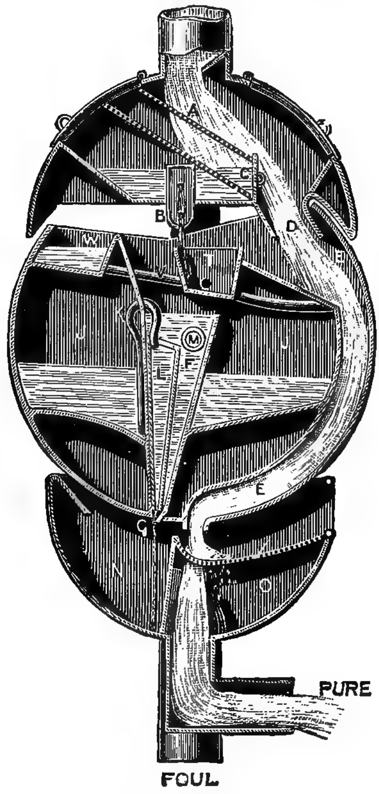

Fig. 83.—Section of vertical separator; pure water passing to storage.

for surplus water. In moderately heavy rain the main volume of the water flows through this spout D into the delivery pipe E, running round the right hand of the canter; a small proportion only passes through the strainer and out of the small holes B into the funnel F that terminates in the small hole G.

In a very slight rain the whole of the water passes through the strainers and the hole at B into F, and when it is not enough to effectually wash the roof it all escapes through G without making the canter move. When there is more rain than can pass through the hole G, it rises in F and L, and a small quantity runs over the side of the funnel, slowly filling the chamber J. When J is filled to a certain height, it overbalances the canter and makes the water run to storage through O, as shown in fig. 83. This change in position causes

the water from B to run into T, and cease to run into F. As the water sinks in F it also sinks in L, causing the siphon K to act and empty the chamber J. Meanwhile some of the water from T will have been running through the pipe V into the little chamber W, and the weight of this water will prevent the canter recanting until the water ceases to run from the roof.

As soon as W is empty, the canter rights itself, ready for the next rainfall, the right-hand side of the canter being heavier than the left when it is empty. By means of the joint action of the sluice O and the holes at B and G, the flow of water in the working part of the separator is so regulated that the chamber J is filled to the canting point as soon as a certain quantity of rain has fallen.

One of the chief defects of a rain-water supply is its scantiness and uncertainty. A rainfall of 25 inches per annum is equal to 2,523 tons per acre, or 565,380 gallons yearly; and even if this were all collected and stored without loss, it would suffice for 62 persons only, each person being allowed 25 gallons per diem. During times of drought, when evaporation is usually great, it is manifest that a rain-water supply must be deficient, except where only a small number of persons has to be supplied.

In Venice, where there is a considerable rainfall, where ordinary wells are impossible, and where there are neither roads, nor horses or other draught animals, and where all the circumstances are apparently favourable, the water-supply for drinking purposes was until recently derived from rainfall. The water was collected from all available gathering areas and discharged into underground tanks filled with sand. The water was thus filtered during its passage through the sand, into which tubes or little wells with impervious sides are sunk, and reach nearly to the bottom of the sand. The water was pumped through the tubes in a clear condition. This system is one of downward filtration of a simple, and it is said of effective character.

If rain-water is to be used for drinking purposes, it should always after collection be filtered through sand and charcoal, or other equivalent material, so as to remove suspended matters, before storage; and should then be kept for some time in carefully covered and well-aired tanks or cisterns, lined with slate or other impervious non-metallic material. A good plan is to pass the water from a Roberts' separator through a conduit sufficiently wide to considerably diminish the velocity of the current, and over a catch-pit which will retain the grosser suspended particles. The conduit should then make a considerable dip, so as to deliver the water at the bottom of the filter, though it should pass in an upward direction to an effluent pipe conveying the filtered water into a covered slate-lined tank. The filter may consist of successive layers of coarse sand; charcoal, magnetic carbide, or other equivalent purifying material; coarse gravel; and sand.

When iron tanks and pipes are used for the storage and distribution of rain-water, the metal becomes rapidly corroded; and no useful purpose appears to be served by coating the iron with zinc (galvanising); for the zinc is quickly removed, and the water becomes turbid with zinc compounds, and even contains this metal in solution. This zinc-caused turbidity persists until all the coating of zinc has been removed.

The following approximately correct rules are useful as to rainfall, and yield of rain water:—

The rainfall in the wettest year is double that of the driest year.

The fall in the wettest year is one-third more than the average rainfall.

The fall in the driest year is one-third less than the average rainfall.

Upland Waters

Many of the large northern manufacturing towns of this country, such as Glasgow, Liverpool, Manchester, Leeds, Sheffield, and Keighley, are supplied with upland water. Glasgow is supplied from a natural reservoir—Loch Katrine. The new Liverpool supply is derived from a gathering ground in Wales, artificial reservoirs being formed for its storage. The usual method of obtaining such a supply is to impound the water flowing off from the surface of a large, barren, uninhabited area of land, where commonly the rainfall is high, and the amount of water that percolates through the soil small as compared with that which flows off the surface. The water is collected into streamlets, which combine to form one large brook at the bottom of a valley. A dam is built across this at a convenient spot, and the water is headed back into the reservoir thus formed. Loch Katrine is a similar natural reservoir or lake, and Lake Thirlmere, from which Manchester is to receive its new water-supply, is also a similar lake, which is to be increased in capacity, and its level raised fifty feet, by a dam built across one end of it. The natural outlet of Lake Thirlmere is to the north, but the water for Manchester is to be obtained by tapping the southern end of the lake, and drawing off the necessary quantity of water by means of a tunnel through Kirkdale Pass. In dry seasons the reservoirs will not be full. In flood-time the excess of water flows over a weir at a fixed height into a 'bye wash' or side channel, and thence into the main stream.

The probable yield of a gathering ground is a very important consideration, and the estimation of the available yield of water from a given area is by no means a matter of easy solution. Mr. Bateman's views as to the quantity of rainfall available for water-supply are set out in the 'Report of the Royal Commission on Water-Supply (1869).' Where the average rainfall in a mountainous district is 75 inches, he estimates that 80 per cent. of that amount, or 60 inches, may be taken as the average fall of two or three consecutive dry years. In such rainy districts the loss from evaporation and absorption averages from 9 to 16 inches, and he adopts 12 inches as the mean for North Wales. This 12 inches deducted from the 60 inches above leaves 48 inches, or 64 per cent. of the total average rainfall, as the net available rainfall when the total average rainfall is 75 inches. But for greater security, Mr. Bateman diminishes again the last result by 25 per cent. and takes 36 inches as the estimated available proportion of the rainfall of 75 inches—i.e. 48 per cent. (or practically one-half), on which to base his calculations. In the old Manchester waterworks, with an estimated rainfall of a little more than half 75 inches, he states that he collected 32 inches of rainfall.

Other eminent authorities think Mr. Bateman's estimate of the proportion of available supply too high. Mr. Thomas Hawksley says it is known to be impossible, by any system of reservoirs that can be constructed, to deal with more than the average of three consecutive years of minimum fall. The minimum year has about one-third less than the general average rainfall; and in the three consecutive driest years the average fall is almost precisely one-sixth less. Thus, with an average rainfall of 45 inches, he would deduct one-sixth, leaving 37½ inches as the average quantity of the three minimum years, and in a district partly lowland and partly highland, as, *e.g.*, in North Wales, he would deduct 13½ inches from the above 37½ inches for loss by evaporation, &c., leaving 24 inches only as the net available rainfall, where 45 inches is the average annual fall—or about 55

per cent. of the whole rainfall (*op. cit.*). The experience of recent years has shown that even this estimate of Mr. Hawksley's of net available rainfall may sometimes be excessive.

Sir Robert Rawlinson (*op. cit.*) considers that a deduction of one-third should be made from the average to arrive at the minimum rainfall of any one year. Mr. J. G. Symons, taking the true mean rainfall of a wet district (the Lake District) as 77 inches, infers that the mean of three dry years would be 80 per cent. of this amount, or $61\frac{1}{2}$ inches; but in the driest years he would take only something like 66 to 68 per cent.—say two-thirds—of the average as the true dry season rainfall.

In this connection it may be remarked that the proportion of evaporation to rainfall is very variable, and that the data afforded by observation in one country or locality are inapplicable to another dissimilar district, or to a country with a widely different climate. Hence the recorded results of observations made are widely discrepant and irreconcilable. Formerly it was held by French hydraulic engineers that evaporation always exceeds rainfall (Geikie's 'Text Book of Geology,' p. 360), but it has been since shown that, except in unusually dry years, rainfall invariably exceeds evaporation. At Lea Bridge, near London, the average recorded rainfall of ten years was 25·5 inches, and the evaporation from the surface was 21 inches per annum (Symons's 'Brit. Rainfall for 1869,' p. 162). The discharge of rivers, as compared with rainfall, varies, of course, to a still greater extent than the proportion of evaporation to rainfall. In the Thames basin, and in most of the river basins of Great Britain, it is said that from one-fourth to one-third of the rainfall is discharged by rivers. The Seine at Paris is stated to carry down one-third of the rainfall of its basin, and the Mississippi is also stated to discharge one-fourth of the rainfall of its collecting area, whilst the Missouri discharges only one-sixth of the rainfall of its basin. But some American rivers are computed to discharge nine-tenths of the rainfall of their respective basins.

Mr. Symons has deduced from meteorological returns the general result that in any given district the wettest year of a series will have in the British Isles a rainfall nearly half as much again as the mean; that the driest year will have one-third less fall than the mean, and that the driest three consecutive years will each have one-fifth less than the mean rainfall of a long series of years. Now let R.m. be the mean average rainfall, then we have:

Rainfall in the wettest year	1·5 R.m.
,, ,, driest ,, ...	$\frac{2}{3}$ R.m.
Mean of the driest three consecutive years . .	0·8 R.m.

Thus, if Q = daily quantity in gallons for all purposes required to be supplied from the reservoir, then, E being inches of rainfall evaporated,

$$Q = 62\ A\ (0{\cdot}8\ \text{R.m.} - E).^{1}$$

Which gives the relation between the area of the gathering ground (A), and the quantity it will supply (Q), and by substituting 150 Q for Q in wet, and 200 Q for Q in dry districts, we arrive at the storage capacity of the reservoirs required ('Pole on Water-Supply,' p. 24).

Characteristics of Upland Surface Waters

Upland surface waters may be derived from either igneous or metamorphic rocks; but the analyses made for the Rivers Pollution Commissioners (6th

[1] Mr. Pole's factor is 62·15. According to the new determination (recently legalised) of the weight of a cubic inch of water at 62° F. (252·286 grains) the factor should be 61·89. I have adopted 62 as sufficiently exact. [T. S.]

Rep. 1869) show that the upland surface waters from the exposed Metamorphic, Cambrian, Silurian, and Devonian rocks in Great Britain do not differ materially in composition—except, perhaps, as to their minuter mineral constituents—from those derived from the harder igneous rocks. Their total solid constituents were found to range from about 1 to 9 grains per gallon, the average amount being 3·5 grains. They are pure, soft waters, not infrequently destitute of chalk; and they sometimes contain free acid or acid salts. Organic substances are present in small quantity, and are chiefly of vegetable origin. These waters are, however, often peaty, bitter, and highly coloured; and peaty waters are prone to cause temporary diarrhœa when drunk by persons unaccustomed to their use. They also dissolve lead freely.

The upland surface waters from the Yoredale and Millstone Grits and the non-calcareous portions of the Coal Measures contain rather more saline constituents than the above-named waters; these varying from about 3 to 10 or 11 grains per gallon, according to the analyses made for the Rivers Pollution Commissioners; the average being, however, little more than six grains per gallon. Those from the Lower London Tertiaries and Bagshot beds are still more saline; whilst those from the calcareous portions of the Silurian and Devonian rocks contain from 8·5 to 10 grains per gallon of saline solids. Those from the calcareous portions of the Mountain Limestone contain from 8·5 to 16 grains per gallon of solid matter, and are of moderate hardness. The surface waters from the calcareous portions of the Coal Measures may contain as much as 38 grains per gallon of saline matter, with an average of about 16 grains, according to the Rivers Pollution Commissioners (*op. cit.*), and their hardness may be considerable. The upland surface waters from the Lias, New Red Sandstone, Conglomerate Sandstone, Magnesian Limestone, and Oolite formations approximate in composition to those from the Mountain Limestone.

The surface waters from cultivated land, when this is not calcareous, do not appear to contain much more solid matter than those from upland uncultivated soils, according to the Rivers Pollution Commissioners, who give the average amounts as 4·5 and 6·5 grains per gallon respectively. It is chiefly the organic impurity which, as might be expected, is increased by the cultivation and manuring of the soil. Where, however, the soil under cultivation is calcareous, the saline constituents of the surface water rarely fall below 14 grains, and may rise to nearly 80 grains per gallon.

The land drainage from a highly manured soil usually yields an impure water. The carbonic acid formed during the decomposition of organic matters, whether animal or vegetable, greatly increases the solvent action of these waters upon calcareous matter.

Water stored in large lakes is, as a rule, potable, safe, and little liable to serious pollution from animal matters; but that from very small lakes and ponds is often more largely contaminated, since the proportion of sewage and drainage from manured land is great in proportion to the volume of the effluent water. A vexed question relates to the decomposing vegetable matter and the organisms of pond life both of animal and vegetable nature, usually present. The minute vegetable organisms—often invisible to the eye—present in such waters often render it difficult to store such waters without offence; and under these circumstances such waters cannot be considered to furnish satisfactory supplies. These waters are generally satisfactory when carefully filtered; but they are apt to clog the filters, which require careful management and frequent renewal of the filtering medium.

It has been stated that water abounding in certain forms of algæ has proved fatal to the animals which drank of it.

It may be useful to summarise what has been stated as to upland surface waters from various geological formations and soils as follows:

The Rivers Pollution Commissioners, 1868 (*op. cit.*), ascertained that waters from the various geological formations of the British Islands had the following composition:—

1. *Upland Surface Waters from Igneous Rocks.*—Solids 1·1 to 8·9 grains per gallon; average 3·6 grains. Hardness 0°·6 to 4°·1; average 1°·5.

2. *Upland Surface Waters from Metamorphic, Cambrian, Silurian, and Devonian Rocks.*—Solids 1·5 to 8·7 grains per gallon; average 3·6 grains. Hardness 0°·3 to 4°·8; average 1°·8.

3. *Upland Surface Waters from the Yoredale and Millstone Grits, and the Non-Calcareous portion of the Coal Measures.*—Solids 3·2 to 10·5 grains per gallon; average 6·1 grains. Hardness 0°·6 to 6°·3; average 3°·3.

4. *Upland Surface Water from Lower London Tertiaries and Bagshot Beds.*—Solids 4·1 to 9·2 grains per gallon; average 5·9 grains. Hardness 1°·3 to 3°·9; average 2°·7.

5. *Upland Surface Water from the Calcareous portions of Silurian and Devonian Rocks.*—Solids 8·6 to 10·1 grains; average 9·6 grains. Hardness 5°·2 to 6°·7; average 6°.

6. *Upland Surface Water from Mountain Limestone.*—Solids 8·7 to 16·4 grains per gallon; average 11·9 grains. Hardness 6°·9 to 10°·2; average 8°·9.

7. *Upland Surface Waters from the Calcareous portion of the Coal Measures.*—Solids 7·1 to 54·1 grains per gallon; average 16 grains. Hardness 4°·3 to 17°·5; average 8°·6.

8. *Upland Surface Waters from the Lias, New Red Sandstone, Conglomerate Sandstone, and Magnesian Limestone.*—Solids 7·8 to 18·4 grains per gallon; average 13·2 grains. Hardness 4°·2 to 17°·4; average 9°·9.

9. *Upland Surface Water from Oolites.*—Solids 12·2 grains per gallon; hardness 8°·7—in the one sample analysed.

10. *Surface Waters from Cultivated Land in Non-Calcareous Districts.*—Solids 3·7 to 12·7 grains per gallon; average 6·7 grains. Hardness 1°·5 to 7°·1; average 3°·4.

11. *Surface Waters from Cultivated Land in Calcareous Districts.*—Solids 9·3 to 77·3 grains per gallon; average 20·7 grains. The solids rarely fell below 14 grains per gallon. Hardness 5°·5 to 47°·1; average 14°·4. The hardness rarely fell below 14°.

Spring Waters

Springs yield water-supplies of a varied character. They may be classified under three heads: land springs, main springs, and intermittent springs or bournes.

Land springs are springs of water formed by the percolation of water through superficial porous soils, such as sand, gravel, or alluvial earth, overlying impervious strata, such as clay. Where the two strata—the impervious and the pervious—crop out to the surface, or when the line of junction of the two strata is tapped, a land spring appears. Such springs are frequently met with in the carrying out of drainage and sewerage works, and during the sinking of wells. Their yield of water is uncertain and precarious, depending upon the extent of available porous collecting area, which may be small. They are, however, frequently replenished by the percolation from heavy summer showers which do not affect deeper springs and wells; but they

are also affected by season, the yield of water increasing during the winter months, October to March, and decreasing during the summer months, April to September.

In adopting a land spring as a source of water-supply for a house, the yield of water at one particular period of the year—especially the yield in the spring—cannot be relied on as to quantity. The autumn yield is a safer guide to the abundance of the available supply. It is always safest to gauge the spring several times during the year, and more especially during the summer and autumn seasons.

Main springs are those deep-seated springs whose source is the main water percolating through great thicknesses of porous rock overlying an impervious stratum; and frequently the collecting area is remote from the spring itself. These springs are chiefly met with in regular geological formations, such as the chalk and green sand. When the stored-up water is confined by an overlying stratum of impervious material, we have the conditions requisite for the formation of an artesian well. On boring through such an upper impervious stratum of rock till the water-bearing stratum is penetrated, the head or pressure of water in the water-bearing layers of rock may force the water up the bore-hole to a considerable height. The latent spring is, in fact, tapped and made available for use. Good examples

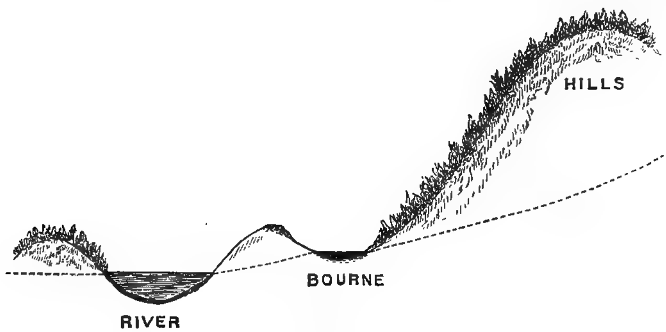

FIG. 84.

of artesian wells are met with in the Thames Valley, and furnish excellent water-supplies. On the banks of the river Wandle, near Merton in Surrey, the water in such wells rises to the level of a few feet above the surface of the soil, and by means of inverted J-shaped pipes is discharged in such a manner as turn water-wheels.

Intermittent springs, or 'bournes,' as they are technically termed, were formerly supposed to be formed by natural syphons, emptying from time to time underground reservoirs of water; but no such syphon emptying an underground reservoir has ever, in fact, been discovered; and all the phenomena connected with these springs can be satisfactorily accounted for on simpler principles. Such springs are usually found near the chalk, as e.q. near Croydon, and at Assendon.

In fig. 84 the dotted line represents the level of the underground water in the neighbourhood of a valley traversed by a river and bounded on one side by hills. This line of level rises from the river to the hills, in which the water will stand at a much higher level than at the river; this being invariably the case with underground water. In winter the declivity of the underground water-level will be much steeper than in summer. The appearance and disappearance of the bourne will depend upon whether the water-level at the spot marked 'Bourne' comes to the level of the surface, or

remains beneath the impervious strata. Bournes nearly invariably make their appearance in winter, when the level of the underground water is highest, and disappear in summer, when this is lowest. In 1879 there was, however, a remarkable exception to this uniformity, for in that year the Assenton Spring broke out in June. In 1879 the spring rains were excessive, and percolation into the deeper strata of rock, which in summer is usually nil, took place to large extent; and thus the appearance of the spring in the unusual month of June is readily explained. Spring- and well-waters may be classed together; and it is among these waters that the widest differences, as to the quality and quantity of their saline constituents, is encountered. Waters drawn from shallow surface wells may exhibit all the characteristics of surface waters from the same locality; or, more commonly, they are charged with the washings of, and percolations of surface water through, a shallow soil loaded with animal and vegetable organic impurities. Waters from deep springs and wells, on the other hand, are usually of practically uniform temperature, whatever be the variations in the temperature of the atmosphere, and when from similar soils show but little variation in their saline and other constituents. With respect to their saline constituents, there is the utmost variation in their composition; and these waters may vary from a fairly soft, palatable water, to that of a saline, chalybeate, arsenical, or purgative fluid. Their freedom from organic contamination is usually almost complete; and hence, if their salinity be not too great, and if they are free from more than mere traces of potent medicinal substances, such waters are agreeable refreshing beverages, and are well adapted for drinking purposes and for town water-supplies. Deep well-waters, indeed, yield the best water-supplies, and those to which the fewest exceptions can be taken, save on the score of hardness or the cost involved in pumping. The water-supply, on the contrary, from shallow wells is, as a rule, bad, and always dangerous if the well be in the proximity of dwelling-houses, middens, privies, ashpits, stables, and the like sources of contamination; for the purity of such waters is at any moment liable to be impaired by the sudden irruption of organic filth and the soakage of liquids. The writer has found the shallow wells of London to yield water containing as much as 200 and even 300 grains per gallon of solids—hard, abounding in sulphate of calcium—and yet withal clear, sparkling, and pleasant to the taste. A memorable instance of an outbreak of Asiatic cholera following the use of such a water is recorded in the classical instance of the Golden Square pump, by Dr. Snow. This case will be again adverted to.

When shallow wells are sunk into an alluvial, gravelly soil, in the immediate proximity of a river, they may become contaminated with filth carried laterally to great distances, owing to the 'set' of the ground-water in a particular direction, generally towards the bed of a river. Such underground streams are by no means uncommon, and, when pure, form uniform and excellent supplies, such as those which have furnished water to Dresden.

Under other conditions, shallow wells should, if possible, be avoided as sources of water-supply. They are very prone to be contaminated with organic filth, derived from the soakage of sewage and slop-water into a porous soil. It was formerly supposed that a well drains an area extending over a distance in radius twice the depth of the well. No general rule can, however, be laid down, and often the distance is much greater than this. Such wells can never be considered safe, unless they are sunk through an impervious bed of soil into a porous stratum beneath, and are well cemented down to the clayey stratum. Wells which do not conform to this rule are too abundant in most rural districts, and are fertile sources of mischief.

Around a well, the surface of the ground-water in the soil will be found to take the form of a hollow inverted cone, with its apex at the level of the water in the well, the base of the cone merging imperceptibly in the general level of the adjacent ground-water. When the well is pumped, the apex of the cone will be depressed, and its area will be extended—the cone becoming flattened out. The drainage area of the well will thus be increased, and if there be any cesspool, pervious sewer, or leaky drain within the area of the cone, the polluting liquids will be drawn into the well by suction. Hence the great danger attendant on the use of shallow wells, and all wells sunk into pervious soils only.

Some years ago the town of Croydon in Surrey was visited by an epidemic of typhoid fever, which was traced to the water derived from deep wells. Mr. Baldwin Latham made observations which showed that when the pumps were worked the level of the ground-water was lowered, and sewage was sucked out of the sewers, passing, as he alleged, into the wells supplying Croydon.

Wells in proximity to the sea generally afford a saline and somewhat brackish water, containing excess of magnesium and sodium salts, without doubt derived from the presence of the salts of sea-water. Even when the wells are sunk to a considerable depth below the level of the sea, it must not be supposed that there is any appreciable direct percolation of sea-water into them, for it will be found that the 'set' of the underground water around the well is towards the sea. It is more probable that the advent of sea-salts is due to liquid diffusion, the salts diffusing backwards into the well. If it were otherwise, the water in the wells would be more than brackish, and would be salt water. That sea-salts will find their way into wells situated at a great distance from the sea or a tidal river, is shown by the observation of the late Dr. de Chaumont, who found in a place near the Humble River in Hampshire, that the tide affected the water at a distance of 2,240 feet, or nearly half a mile; the well itself being 83 feet deep, and 140 feet *above* mean water-level. ('Lect. on State Med. 1875,' p. 91.)

Driven Wells or Tube Wells.—These are also termed Abyssinian wells, in consequence of their having been used during the Abyssinian war to supply water to the British troops. They are very serviceable in country districts where the shallow surface wells afford polluted supplies, and where a better and purer water can be obtained by penetrating through an impervious clay into the more porous water-bearing strata beneath. Their construction is very simple. An iron pipe, $1\frac{1}{2}$ to 2 inches in diameter, is furnished at its lower end with a hard steel point, above which the pipe is pierced with holes to admit of the inflow of water. The pipe is driven perpendicularly into the soil by means of a mallet or falling weight; a second length is attached by means of a joint or coupling, and the lengthened pipe is again driven into the ground. The addition of successive lengths of pipe is continued until water is reached. Finally a small pump is attached to the uppermost length of pipe, and the well is complete.

Leakage of sewage into tube-wells is much less likely to occur than into ordinary shallow wells. Nevertheless, when the pump is vigorously worked, sewage may be drawn into the tube from a considerable distance. Of course, tube-wells are not adopted for any but limited supplies of water.

Besides underground springs on the continent of Europe, and also in America, it is not uncommon to obtain supplies of drinking water from underground tanks, tunnels, and galleries sunk parallel to the bed of a river, and in the proximity of this. The theory of these constructions was that water would percolate or filter from the bed of the river into

the reservoir constructed for its reception. This supposed percolation can, however, occur but rarely; and nearly invariably it is the underground water, intercepted in its passage to the river, that furnishes the water for use. Should the underground water be not intercepted it gradually finds its way to the river, *into* and not out of which percolation almost invariably takes place. It is well known, for instance, that the river Thames is in this way largely fed by springs of such ground-water at various points in its course.

That the above is the true explanation of the source of water-supply where such underground tanks are constructed is proved by the experience of Toulouse, where the supply of water was largely increased by removing such a tank to a greater distance from the river Garonne, and intercepting the ground-water at a higher level; for, as is elsewhere stated, the level of the ground-water invariably rises as we recede from a river. The experience of Dresden is also significant, and to the same effect. The relative temperatures of the river, the ground-water generally, and the water in the tanks in summer—and, further, the hardness of the water in wells near the river—all support the same view as to origin. Lastly, it is known that by pumping from a well near the banks of a river, as e.g. the Elbe, the level of the ground-water is depressed over a wide area. It is manifest, too, that were the water of a river to percolate outwards through its bed, this would soon be so silted up by the finely divided suspended particles in the water as to put a speedy stop to the percolation. On the other hand, the ground-water having no such suspended particles, when filtering from a coarser into a more finely divided stratum, will not clog the pores of the river bed, but rather will tend to keep these open. It is remarkable that the underground tanks and galleries referred to, though constructed on a false theory, have been so successful as they have generally proved to be.

Occasionally the flow of underground water through fissures in the chalk is utilised, and made to furnish an abundant water-supply, which may be of considerable organic purity, as, for example, at Brighton, where the necessary works were devised by Mr. Easton. This is done in the following manner. At Brighton, and other places on the sea-coast, little streams of water may be seen flowing seawards from the higher part of the foreshore. These are commonly but erroneously supposed to be formed by sea-water which has been dammed back into the porous strata at high-water. But when tested these streamlets are found to be composed of fresh water. Further examination shows that where the coast is formed of pervious strata, as, for example, chalk, the level of the underground water forms a curve, beginning at a point between high and low-water level, and rising as the sea is receded from. The head or pressure of the underground water is always forcing, or tending to force, the underground water out of the rock at the point where the level of this comes out on the foreshore, whence at low water the issuing water becomes visible. In winter the water-level in the soil forms a steeper declivity than in summer, when the underground water stands at a lower level in the subsoil. By sinking galleries into the chalk behind Brighton, and parallel with the line of sea-coast, down to a level with the low or summer level of the underground water, the rills of this constantly passing seawards through the fissures in the chalk rock are tapped, and utilised for water-supply.

In adopting such a source of water as has been described, great care is previously necessary to ascertain that the water is uncontaminated, since fissures in the chalk are liable to serve as conduits for sewage from great distances; and it is these chalk fissures which often render a water-supply drawn direct from the chalk a polluted or suspicious one.

The water derived from deep artesian wells in the British Isles is usually of excellent quality, and remarkably free from organic matter. Exceptionally such wells yield a brackish water. In England, artesian wells are often of great depth, being sunk through the chalk and into the lower greensand formation where this is covered by the gault. But artesian wells are not always or necessarily sunk in the above-named geological strata. What is required for their formation is that a well be sunk through an upper impervious stratum into a subjacent pervious and water-bearing stratum, in which the water is confined under such a head or pressure that when tapped it rises in the well-tube or bore-hole to a considerable height, or even to the surface. Unfortunately the water from artesian wells is often saline, and is the water holding in solution the salts of saline beds of remote geological formation, probably from lakes and inland seas. But when not unduly saline, these waters are of excellent quality, clear, colourless, of uniform temperature throughout the year, and pleasant to the taste. These are, however, sometimes rather hard; but those in and about London are decidedly alkaline from the presence of several grains of bicarbonate of sodium in each gallon of water, and are hence somewhat soft. Some deep well-waters are warm, as, *e.g.* those of Bath; and then are unfitted for ordinary drinking purposes. Others, again, have a slight odour of sulphuretted hydrogen, speedily lost on free exposure to the air. These feebly sulphuretted waters may be troublesome when stored in cisterns, in consequence of the readiness with which they become filled with filamentous vegetable growths.

Sometimes water is obtained from wells and borings made direct into the solid chalk, which is not usually a water-bearing rock. In such cases a bore-hole is driven into a fissure or fault in the rock, such fissures being common in the chalk, and acting when filled with water as underground streams. Where the fissures have one general direction, an adit or channel may be made at right angles to their course—as at Brighton, where, as has been already stated, the water is systematically abstracted to form the town water-supply.

The proposals that have been made in the instances of London and other large cities to substitute a supply from deep wells for a river-supply have generally been viewed with doubt by the majority of engineering authorities. Deep wells may yield a tolerably constant and copious supply of water, if not unduly taxed; but it by no means follows that were a much larger supply attempted to be obtained from these strata, which yield a moderate supply, the yield would be commensurate with anticipations. The quantity of water present in strata at any one time is limited; and the experience derived from the artesian wells in a London district is that the level of the deep water, and hence its head or pressure, is steadily falling year by year, and that the underground supply from such wells is by no means an unlimited one. At Guy's Hospital, the artesian well formerly yielded a supply adequate to the needs of the institution; whereas now it affords only one half of the requisite quantity, and the well is pumped on alternate days, and not every day as formerly.

Exceptionally, an artesian well may furnish a polluted water-supply: and some have furnished unmistakable evidence of the sources of their impurities in the shape of dead fish, marsh plants, roots, seeds, &c. It is supposed that in some of these cases these materials have been conveyed in subterranean conduits from great distances.

Generally, it may be said that spring waters, if not of a thermal, medicinal, aperient, or chalybeate character from the too great or unusual nature of their constituents, furnish pure and excellent supplies of water. Indeed, the German Public Health Association some years ago arrived at the conclusion

that spring waters alone—either those coming naturally to the surface, or obtained from wells—are the only admissible sources of water-supply. This too sweeping resolution was, however, subsequently rescinded. Nevertheless, it shows what a high value German hygienists very properly attach to springs as sources of the very best water-supply.

The advantages of spring waters have been thus summarised by the Rivers Pollution Commissioners :—'That preference should always be given to spring and deep-well water for purely domestic purposes, over even upland surface water, not only on account of the much greater intrinsic chemical purity and palatability of these waters, but also because their physical properties render them peculiarly valuable for domestic supply. They are almost invariably clear, colourless, transparent, and brilliant, qualities which add greatly to their acceptability as beverages : whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer, and prevents them from freezing readily in winter. Such waters are of inestimable value to communities, and their conservation and utilisation are worthy of the greatest efforts of those who have the public health under their charge.'

The Rivers Pollution Commissioners, 1868, analysed a large number of well waters from shallow wells with the following results :—

1. *Waters from shallow wells in or upon Silurian Rocks and Gneiss.*—Solids 2·4 to 70·1 grains per gallon; average 16·7 grains. Hardness 2°·4 to 29°·1; average 7°·5.

2. *Waters from shallow wells on Devonian Rocks.*—Solids 8·5 to 73·6 grains; average 27·5 grains. Hardness 3°·5 to 39°; average 14°·6.

3. *Waters from shallow wells on the Yoredale and Millstone Grits.*—Solids 4·1 to 93·5 grains per gallon; average 35·1 grains. Hardness 2° to 63°; average 22°·1.

4. *Waters from shallow wells on the Coal Measures.*—Solids 6·6 to 154·6 grains per gallon; average 48 grains. Hardness 2°·4 to 98°·6; average 24°·4.

5. *Waters from shallow wells in or on Mountain Limestone and Magnesian Limestone.*—Solids 32·1 to 76·2 grains per gallon; average 50·4 grains. Hardness 28°·5 to 62°; average 40°·9.

6. *Water from shallow wells in or on New Red Sandstone.*—Solids 14·4 to 168·1 grains per gallon; average 71·1 grains. Hardness 12° to 89°; average 34°·5.

7. *Water from shallow wells in or upon the Lias.*—Solids 26 to 214·8 grains per gallon; average 77·8 grains. Hardness 1°·9 to 81°·8; average 35°·8.

8. *Waters from shallow wells in or on the Oolite.*—Solids 21·7 to 188·7 grains per gallon; average 64 grains. Hardness 16°·1 to 55°·2; average 32°·4.

9. *Waters from shallow wells in or on the Upper and Lower Greensand and Wealden Beds.*—Solids 7·4 to 266·8 grains; average 50 grains. Hardness 2°·7 to 56°·4; average 19°·7.

10. *Waters from shallow wells in or on the Chalk.*—Solids 22·7 to 111·4 grains per gallon; average 55·6 grains. Hardness 16°·7 to 50°; average 30°·5.

11. *Waters from shallow wells in Gravel on the London Clay.*—Solids 22·3 to 277·5 grains per gallon; average 71·2 grains. Hardness 10° to 133°·7; average 35°·6.

12. *Waters from shallow wells in Bagshot Beds.*—Solids 16·2 to 200·8 grains per gallon; average 82·2 grains. Hardness 9°·2 to 92°·2; average 38°·5.

13. *Water from shallow wells in Fluvio-Marine Series.*—Solids 5·7 to

46·3 grains per gallon; average 19·1 grains. Hardness 3°·2 to 25°·5; average 10°·8.

14. *Waters from shallow wells in Alluvium and Gravel.*— Solids 20 to 224·5 grains per gallon; average 69·6 grains. Hardness 3°·2 to 106°·7; average 33°·3.

River-water

River-water varies greatly in quality, and also as to its organic purity. Some rivers yield water of unimpeachable quality: whilst others, as e.g. the Irwell at Manchester, afford only a filthy, disgusting liquid. The saline constituents of river-water vary according to the kinds of soil through which the tributary streams flow, the springs or ground-water which find their outlet in the bed of the river, and the nature of the soil through which the river itself flows. Generally, it may be stated that a river-water is less hard and saline than the water of its tributary streams in the lower part of its course; but it may be much harder and more saline than the waters of the upper tributaries, if these flow from a country abounding in igneous rocks. The chalk held in solution by carbonic acid in the contributory springs becomes in part thrown out of solution by the escape of carbonic acid on exposure to the atmosphere during flow in the river, and this tends to diminish the hardness of the water.

The liability to contamination of the water of rivers in agricultural, and still more in manufacturing districts, is a great drawback to the use of such waters as sources of domestic supply. Fortunately, the self-purifying action going on in rivers is very great, and there is the compensating advantage that in large rivers of considerable length the supply, as in the case of the Thames, is fairly constant and abundant; and it must be admitted that river-waters, even after a few miles' flow and efficient filtration, so as to remove all suspended matters, sometimes form a fairly safe source of supply; and in proof of this the supply of London with drinking water taken from the Thames above the tidal lock at Teddington may be adduced as a signal instance. Before the chief water-supply of the metropolis was by statute compelled to be taken exclusively from the river above the unpolluted reaches, cholera and perhaps other diseases were produced among the inhabitants of London by the drinking of polluted river-water; but since about 1866, when the change was effected, no appreciable amount of disease has ever been proved to have been caused in the metropolis of England by means of the filtered water as delivered to the consumers. This, coupled with the fact that no source of supply so abundant, sure, and uniform exists within a reasonable distance of the metropolis, has hitherto effectually stood in the way of the adoption of any other water-supply for London.

What has just been said must not be taken to indicate that the pollution of a river-water by filth is of no consequence, provided there be a good flow of a few miles before the intake of a drinking water-supply is reached. The writer merely wishes to indicate that the danger attending the use of river-water which has been antecedently polluted has been exaggerated. The late Professor Rolleston expressed an opinion that the introduction of cholera germs into the Thames at Oxford might result in an outbreak of that disease in London, but these anticipations have not been realised. Dr. Frankland has also stated that 'there is no river in the United Kingdom long enough to purify its waters spontaneously if they have once become contaminated with sewage ('Applied Chemistry,' p. 552), a statement to which few would venture to subscribe in the present day. The truth appears to be that rivers are able to get rid of their sewage pollution

by the combined agencies of oxidation, growth of vegetation, and the activities of organisms such as bacteria and the lower forms of vegetable growth; and there is practical but not absolute safety if the polluting material be not introduced in excessive proportion, and the river have a free flow of several miles, especially over a rocky bed and weirs, so as to subject the water to agitation and consequent abundant aëration. The late Dr. Letheby and Dr. Tidy have been the strongest supporters of this hypothesis, which has also received the support of Dr. Odling. Nevertheless, it must be admitted that the experience of 1866 with respect to cholera—the last visitation of that disease—is insufficient to enable a satisfactory conclusion to be drawn, affirmatively or negatively; and more recent experience appears to show that a flow of several miles in a river is insufficient to destroy the activity of the poison of typhoid fever.

Some rivers afford a highly polluted and dangerous water, though directly they may receive no great quantity of sewage, or even none whatever. These rivers are derived from a peaty soil, or from ground-water and springs in a highly porous polluted soil. A signal example is the river Blackwater in Surrey, which comes from the Bagshot Sands, a sandy porous soil, the springs in which are highly impure. It is stated that the Upper Bagshot Sand yields a pure water, whilst the Middle Bagshot Sand yields a highly polluted water-supply.

River-waters in mining and manufacturing districts may become specifically polluted, so as to render them entirely unfit to serve as sources of water-supply. The Fifth Report of the Rivers Pollution Commissioners deals fully with these sources of pollution, in mining districts arising from collieries and coal-washing—iron, copper, lead, tin, arsenic, manganese, and baryta mines; from china-clay works, and from metal manufactures. Their First and Third Reports treat of pollution by manufacturing refuse. The Commissioners (Sixth Réport, p. 418), while admitting that the drainage-water from arable lands is preferable to that from polluted shallow wells, apparently were of opinion that river-water is inadmissible as a source of town supplies, a conclusion which the writer considers far too sweeping.

QUANTITY OF WATER FOR DOMESTIC AND OTHER SUPPLIES

The amount of water needed for domestic and other uses is a matter of important consideration to Medical Officers of Health. In making arrangements for a town supply, he will of course have the aid of the engineer to guide him as to the quantity of water available from a given source; but in rural districts he may have no such assistance. In all cases his advice will be sought as to the requirements for domestic use, both as regards quality and quantity. The adequacy of storage reservoirs is also a matter to which he cannot be indifferent, though advice as to the sufficiency of these to supply the needs of a community during long periods of drought should be obtained from the meteorologist and engineer.

Different estimates have been put forth as to the minimum quantity of water required for domestic purposes, and these vary greatly, and must necessarily vary according to the habits of the community to be dealt with; the social class to which the majority of them belong; the general or partial use of water-closets; and the proportion of the population using household baths. A water-supply that would be ample for a population mostly composed of agricultural labourers would be quite inadequate for the ordinary

needs of a wealthy or even a middle-class town community. Happily, sanitary authorities are becoming alive to the necessity of increasing their water-supplies, and such supplies as would a few years ago have been deemed ample, are now admitted to be insufficient for the maintenance of health and comfort. Yet it must be admitted that greater economy in the use of water is frequently called for, and that enormous quantities of water under our present systems of distribution in towns are simply wasted. The supply should, nevertheless, be liberal, and not niggardly, lest health be imperilled; and it is better to err on the side of excess than to run the risk of want of water and its consequences—impaired health, and disease. On the average of a community, about one-fourth of a gallon per head per day is the quantity of water necessary for drinking purposes. But this is only a small fraction of that required for domestic use. Dr. Parkes measured the water actually used in several houses, and gave the following as the amount used by a man of the middle class, who, he, says, might be taken as a fair type of a cleanly man belonging to a fairly clean household:

	Gallons daily per one person
Cooking	0·75
Fluids as drink (water, tea, coffee)	0·33
Ablution, including a daily sponge bath, which took $2\frac{1}{2}$ to 3 gallons	5·0
Share of utensil and house washing	3·0
Share of clothes (laundry) washing, estimated	3·0
Total	12·08

This quantity is, perhaps, not quite adequate for the needs of the average person in most towns or villages, and it is generally thought that a minimum supply of 12 gallons per head per day is not excessive where no baths are used. A good bath requires 50 gallons of water; and if general baths are used once a week, 5 or 6 gallons per head should be added to the daily consumption (Parkes). Where water-closets are used, an additional allowance of 6 gallons per head per day should be further added; and 2 or 3 gallons should be allowed for waste. Thus we arrive at the following figures, stating the quantity of water required per head per day for purely domestic purposes:

	Gallons
Drinking and cooking	1
Ablutions and general weekly baths	7
Washing and laundry	6
Water-closets	6
Flushing and waste	5
Total	25

A further quantity must be allowed for manufacturing towns and for trade purposes, flushing of sewers, street watering, and the washing of horses and other domestic animals. An allowance of 35 gallons is not too much for a town supply. London has a supply of about 40 gallons, and Glasgow of 50 gallons per head per diem, and these are thought by many sanitarians to be too little.

Dr. Pole, a high authority on all matters relating to water-supply, states, nevertheless (' On Water-Supply,' pp. 13, 14), that the quantity actually required for domestic consumption, including a fair allowance for household purposes, for water-closets, and for ordinary ablutions, is probably not more than about 10 gallons per head per day. But, in addition to domestic consumption, supplies have to be provided for gardens and stables, manufacturing and trade purposes of many kinds, baths and wash-houses, public fountains,

watering streets, flushing sewers, and extinguishing fires; and he says that the quantity for these purposes will vary from 5 to 10 or more gallons per head per day. It is usual, he states, to estimate the normal consumption of a town at 25 gallons per head per day, and he thinks that this quantity will be, or, at all events, ought to be, a sufficient supply for all purposes. Sanitarians will, perhaps, not be inclined to agree with him, and may consider 25 gallons per head per day a sparse supply. With little waste there is no doubt that 25 gallons is a better supply than 35 gallons with no adequate care to prevent avoidable waste. Further, as the above eminent engineering authority insists, water is not only a very expensive thing to provide, and its excessive use not only wastes money, but does positive mischief by increasing the difficulty of carrying it away. There is certainly balance to be struck between the evils of a too abundant, i.e. wasteful, and a too sparing supply of water; but of the two evils the sanitarian will undoubtedly consider the too abundant supply the least. The advantages to a community of an at all times ample supply of water are incalculable; whilst the inconveniences of a too abundant supply—if such be possible—are remediable, and by comparison small.

In hospitals and infirmaries an abundant supply of water is a prime necessity, and a copious extra supply should be stored in tanks in case of fire. In a large London hospital (Guy's), the daily quantity used is 45 gallons *per patient*, or 35 gallons *per head*, including resident staff. This includes laundry water, and that used in the Medical School and Laboratories. But provision should be made for a larger supply than this in case of need. In towns, where possible, the supply for large establishments is economised when supplied by meter. It is a regrettable fact that no efficient water-meter has as yet been generally introduced for the registration of small supplies; if it were otherwise, there is little doubt that great waste of water would be avoided, and that smaller supplies would suffice, if every householder had his water supplied by meter.

The following miscellaneous data relative to the quantity of water requisite for water-supplies are useful:

Waste-preventers of w.c.'s require $\frac{3}{4}$ to 2 gallons for each flush of the closet; even one flush of 2 gallons is usually insufficient to keep the pan clean.

A horse drinks 6 to 10 gallons, a cow 6 to 8 gallons, a sheep or pig $\frac{1}{2}$ to 1 gallon daily (Parkes). Where horses and carriages are kept, at least 16 gallons per horse per day should be allowed for all purposes.

In non-manufacturing towns 5 gallons per head per day should be allowed for trade purposes; and in manufacturing towns double that amount, viz. 10 gallons.

On the strictly constant system of supply, with due supervision so as to prevent waste, 15 gallons per head per day may suffice for a non-manufacturing town, or not much more than half that required under the wasteful intermittent system.

INSUFFICIENT WATER-SUPPLY

The immediate effect on the human body of an insufficiency of drinking water is very manifest in the form of excessive thirst, and an irresistible craving for fluids; and if no other means of gratifying this craving is at hand, the most filthy and disgusting liquids will be eagerly drunk. There is, indeed,

no need of the body so imperative as that for drink. But this condition is not one that often comes under the notice of the sanitarian: rather it is the less immediate results of an insufficient water-supply that he has to deal with and combat, such as want of personal cleanliness, dirty clothing, defective cooking, filthy habitations, accumulations of excreta, uncleansed streets, courts, and alleys, choked drains, and unflushed sewers. The result of these defects is well recognised in the general lowering of the health of the community, the prevalence of typhus and occasionally of typhoid fevers, skin diseases, ophthalmia, and perhaps many other diseases. Other, and generally alcoholic, fluids will be drunk, and thus the degradation of a people having a deficient water-supply will be aggravated. The results are far-reaching. Some half-century ago deficient water-supplies were more common than in the present day, and the First and Second Reports of the Health of Towns Commission for 1844–5 contain abundant evidence of this.

It is difficult to ascertain how far the health of a town suffers from a temporary scarcity of water during a water-famine; but inferentially we should expect the effects to be considerable. Generally, however, in the 'water-famines' of our British towns, the term water-famine is a very relative one; and the supply of water in such times of scarcity of the fluid would not very many years ago have been considered sufficient for domestic use.

STORAGE

The storage of water may be considered under two heads—

A. Storage of public water-supplies.

B. Storage in and about dwelling-houses, &c.

A. *Storage of Public Water-Supplies*

The amount of storage required for the water-supply of a town necessarily varies, not only with the numbers of the community to be supplied, but also according to their habits, and the industrial occupations carried on; and in manufacturing towns the amount of water required for industrial purposes may exceed that required for domestic use. Whatever be the required daily supply, the storage capacity of the reservoirs in rainy districts should equal 150 days' dry weather supply (Pole); and in dry districts 200 days' supply. These estimates apply to the British Isles only; and in drier countries a much larger storage must be provided. Dr. Pole ('Water Supply,' p. 21) has given some simple and useful formulæ for calculating the collecting area requisite, where the rainfall is known, and the loss from evaporation fairly established.

If R = the mean rainfall in a given year, in inches,
E = the estimated loss by evaporation, &c., in inches,
A = the area of gathering ground in acres,

then

$$\text{Gallons of water per day} = 62\,A\,(R - E)$$ [1]

and

$$\text{Cubic feet of water per year} = 3630\,A\,(R - E)$$

Mr. Hawksley's formula for calculating the number of days' storage requisite is to divide 1000 by the square root of the annual rainfall in inches.

[1] See note, p. 233.

Thus, with a rainfall of 36 inches, the day's storage required is $\frac{1000}{\sqrt{36}}=\frac{1000}{6}$ $= 167$ days; and with a rainfall of 64 inches is $\frac{1000}{\sqrt{64}}=\frac{1000}{8}=125$ days.

In rural districts, where the wells supply a too scanty or a polluted water, it is often advantageous to combine a group of villages, introduce water from one source, and thus economise cost. It is a misfortune that in England there is no officer corresponding to the Public Engineer for water-supply who in at least one Continental kingdom (Würtemberg) advises local authorities gratuitously on questions of water-supply, and who, having an intimate knowledge of the whole water-supply of the kingdom, is able to give invaluable information and advice, and whose duty it is to see that economy of cost is exercised. In all schemes for the furnishing of water to villages—and much more when districts or towns have to be supplied—it is important to have regard to the natural water-sheds, the available percentages of rainfall, and the quantity of the movements of the ground-water; and these data can only be furnished by a technically skilled officer, whose knowledge extends much beyond the requirements of one particular district.

All storage reservoirs should be well protected from contamination by cattle, and by excreta of human beings. They should be kept free from weeds, some of which may communicate an unpleasant taste to the water; and all dead and decaying vegetable matter is more or less injurious. When in the neighbourhood of towns and factories, the reservoirs should be covered, so as far as possible, to exclude contamination by solid particles floating in the atmosphere. The strength and stability of reservoirs are matters foreign to the scope of this article.

But in all cases before a public supply is stored in covered reservoirs the water should be subjected to a process of clarification, which may sometimes be effected by simple subsidence. This process needs in the great majority of cases, however, to be supplemented by filtration, and occasionally by a softening process, of which the Porter-Clark process is the best. These matters will be again touched upon hereafter.

B. *Storage of Water in and about Habitations*

The storage of water in and about a dwelling-house is a necessary evil. In rural districts, where the supply is from wells, such storage in tanks and cisterns is often indispensable. Such tanks and cisterns should be of slate by preference, or, failing this, of iron or galvanised iron. The zinc of galvanised iron is, however, apt to become detached, or even dissolved if the water is soft. A non-corrodible cement may be used for coating the interiors of iron cisterns. Zinc cisterns have all the disadvantages of galvanised iron, and are deficient in strength, so that they are not easily cleaned out without damage being done to the cistern. Leaden cisterns are permissible only when it has been ascertained that the water to be stored exerts practically no solvent action on lead. Cisterns should not be larger than is necessary; their contents should, if possible, be renewed daily, and at all events frequently. They should be covered and protected from all sources of contamination; they should have no direct communication with any cesspool, drain, sink, privy, or water-closet. All storage reservoirs for water should be thoroughly cleansed at least once every three months.

For towns the question of the relative values of the constant and intermittent systems of supply is most important; but the preponderance of opinion is undoubtedly in favour of the constant system as best securing economy of

water, purity, palatability and coolness, and personal and domestic cleanliness. In a no distant future an intermittent supply will, it may be hoped, be regarded as an anomaly.

DISTRIBUTION

Water, in whatever manner it has been stored, has generally to be distributed to houses by means of closed conduits or pipes; and usually the 'head' or pressure requisite for its distribution is obtained by gravitation, although a preliminary pumping into special storage reservoirs may be requisite, where the usual storage reservoir is situated at too low an elevation to secure the pressure necessary to raise the water to the level of the highest houses in the district to be supplied. Wherever possible, this pumping should be avoided on account of its cost. Pipes used for conveying the water from the reservoirs to streets are called *mains*, and are nowadays mostly constructed of cast iron, which is sometimes lined with cement or some kind of varnish-like material, such as Angus Smith's bituminous varnish, in order to protect the pipes from corrosion. From the street mains the water is conveyed into the houses by means of subsidiary and smaller pipes, termed supply-pipes, which are usually of lead. Lead is the most convenient and useful, though by no means the safest metal for the construction of these pipes, and generally for distributing water through houses; and in the end it is perhaps cheapest. All the efforts made to bring about the substitution of other materials for lead in distributing pipes have met with only very partial success. The strength and flexibility of leaden pipes, the ease with which they may be bent and adapted to recesses, and soldered together, with their small liability to leakage, are invaluable, and go far to counterbalance its liability to corrosion in the vast majority of cases. They are, however, liable to corrosion and consequent contamination of the water by the poisonous metal lead. This action of water upon lead will be again adverted to, and discussed in detail.

The only kind of pipe that has entered into serious competition with the leaden pipe is the iron pipe; although a variety of materials have been used, such as tin, lead lined with tin, tinned copper, galvanised iron, earthenware, gutta-percha, bituminised paper, &c. All these have, however, proved to be more or less failures. Leaden pipes lined with tin would at first sight appear to be the most promising substitute for lead, since they combine in a high degree the flexibility and adaptability of this metal, and, as has been supposed, with freedom from corrosion of tin. Their safety as regards protection of the lead from the influence of water is nevertheless illusory, and they are costly. The tin is liable to crack when the pipe is bent, and thus the lead becomes exposed, and being in contact with the less corrodible metal tin, and both in contact with a saline liquid, a galvanic couple is established; and the more oxidisable metal (lead) undergoes solution. Thus the contact with tin actually hastens the corrosion of the lead. The joints also, when made with lead solder, are also liable to corrosion, and the protective influence is thus illusory. Finally, though less corrodible than lead, tin is acted upon by ordinary natural waters; and pipes of block tin, when used for the conveyance of water, have been found deeply pitted from corrosion. But it is generally thought that tin-contaminated water is less harmful than that which contains lead, though accurate observation as to this is wanting. On the whole, when iron pipes can be used, they are the safest from a sanitary point of view. The lining of them with zinc (galvanising) is not often of much use, as the zinc coating is generally rather quickly removed by soft waters.

DOUBLE SUPPLY

It is sometimes difficult to obtain an adequate supply of water sufficiently pure to meet the needs of a community for all purposes; and under such adverse circumstances it has been proposed to have a double supply, one of pure water for drinking and cooking, &c., and another, less pure, for closets, drains, and sewers. So long as the impure supply is under control, and is limited to public and trade purposes, no objections can be raised, except on the score of the cost of distributing a double supply. But for household use a double supply must be deprecated. In a house the supply which is most copious and easily accessible will generally be used by preference, except the impure supply be foul to the senses. Common household experience shows that servants, even of the better class, will, when two taps are side by side, draw water from that which delivers water most freely (generally that from a cistern, where one tap delivers from the main and the other from a cistern). In this respect the majority of people cannot be trusted to make a choice. A double supply for household use ought not to be adopted, except for very cogent reasons.

PREVENTION OF WASTE

There has been much difference of opinion as to the respective amounts of waste attending the adoption of the two opposing systems of public water-supply, the intermittent and the constant systems. It has been urged as an objection to the general adoption of the constant system of supply, that where an unlimited supply of water is at all times obtainable there will be an undue use of water, a large portion of the water taken being allowed to run to waste. Experience under the intermittent system of supply has, singularly enough, furnished fallacious arguments for this contention. Experience under the constant system has belied the above unfounded conclusion. It is not found, with a constant supply, that it is altogether impossible to limit the consumption—or rather consumption *plus* waste—to a reasonable amount. On the contrary, with good regulations, vigilant inspection of cisterns, waste-pipes, and taps, waste is brought within reasonable limits, and the undue use of water may be limited in other directions. To large water-consumers the supply may be by meter; but it has not hitherto been found possible to supply water by meter in all cases. The small meters sometimes used do not act well, and, in fact, they are said to allow the liquid to pass through them unregistered. The same cannot be said of large meters. At all events, Water Companies, charging rates, appear to have an invincible repugnance to supplying water on any but a very large scale by meter. For towns the preponderance of opinion is undoubtedly in favour of the constant system, as best securing economy of water, purity, palatability, coolness, and personal and domestic cleanliness. A prejudice was created against the constant system by the absurd regulations attempted to be introduced so as to prevent waste, such as the delivery of water through minutely constricted pipes so that the water would issue only in a dribble. Such regulations are impracticable, and dangerous in case of fire; and with proper supervision it is found that the substitution of a constant for an intermittent system has actually resulted in the saving of water. Indeed, in the present day, the relative values of the two systems can hardly be a matter of dispute; and no householder who has experienced the comfort and benefits of a constant supply would willingly have a reversion to the

intermittent system. Even for villages—and oftener for groups of villages—a constant supply is nowadays frequently laid on, to the great comfort and advantages of rural populations.

The recent experience of London—now in part having a constant supply—is altogether in favour of the constant system, and shows that with moderate inspection no undue waste or cost is incurred. Moreover, meters have been devised which enable the water companies to ascertain, in case of need, in what particular districts waste or consumption is going on, and thus to arrive at a knowledge as to where more supervision is required. Nor need this supervision and inspection be unduly inquisitorial. The experience of the town of Blackburn is, in this respect, instructive.

In the New World the intermittent system has never been largely introduced. But it must be admitted that the figures given by the Boston (U.S.) Water Board (Buck's 'Hygiene,' vol. i. p. 212) of the several supplies in 1879 of water to eighteen cities of the United States show that the town supplies in the States are larger than in England. The supplies there stated range from 22 to 100 imperial gallons per head per day, with an average of 50 gallons, or about 50 per cent., more than is supplied to London. But the strict comparison of places, widely differing in climate and the habits of the peoples inhabiting them, cannot in fairness be insisted on.

CLARIFICATION OF DRINKING WATER

Spring-waters and well-waters are usually sufficiently clear and free from deposit to need no adventitious aid to render them acceptable to the eye, and palatable. Indeed, such waters, when clear, are best delivered direct to the consumers, so as to avoid contamination by exposure and manipulation. It is otherwise with waters collected from large gathering areas, and with river-waters. These both commonly contain so much suspended matter, and are so much discoloured, as to necessitate a preliminary treatment in order to render them clear, pellucid, colourless, and free from objectionable deposits. Hard waters, especially those from springs, and less often river-waters, may also be improved in appearance and better fitted for domestic and manufacturing purposes, by being deprived of a portion of their mineral constituents before distribution to the consumers. This is best done by the Porter-Clark process.

Clarification by Subsidence

The grosser solid particles suspended in upland surface waters, and in those taken from rivers and lakes during times of flood, are often readily, expeditiously, and cheaply got rid of by simply allowing the water to come to rest in storage reservoirs for a variable period; but finely divided clayey matter is not thus easily removed, and may remain suspended in the water for days, or even weeks. A signal instance of the self-clarification of a turbid river is seen in the case of the water of the river Rhone during its passage through the Lake of Geneva, which acts as a huge subsidence reservoir in which the highly turbid water comes to comparative rest. Thus the water is allowed to deposit the solid suspended matters with which it is contaminated on its entrance into the lake (see p. 263, *post*).

In the waterworks of all large towns, when the water is taken from upland collecting grounds or from streams—natural, or, failing these, artificial reservoirs, are made use of, so as to at least partially clarify the water before it is subjected to subsequent filtration. When discoloured

peaty upland waters are stored in this manner, much of the brown discoloration is got rid of, and it is said that the deeper the reservoirs the more effectually is the colour removed. Thus, in Loch Katrine, the lake which supplies Glasgow with water, the brown peaty water discharged into the lake from its contributory streams loses most of its colour, and is delivered in Glasgow in a practically colourless state. It has been supposed that the loss of colour thus undergone on storage is due to the oxidation which peaty matter undergoes under the influence of light—oxidation being much more active under the influence of light than in the dark. But it is more probable that, although oxidation is undeniable, much of the peaty matter in water is not truly dissolved, but is in a minute state of subdivision which enables it to remain suspended, and that these fine suspended particles subside on standing. The fact that deep reservoirs, which are less readily aërated with oxygen than shallow ones, are more effective than the latter in removing peaty discoloration is against the oxidation theory. It is known that during the bleaching of a peaty water by natural processes, a brown deposit subsides; but whether this is the actual discolouring agent in the water or an oxidation product thereof, is undetermined.

Deep lakes and artificial reservoirs have the great advantage over shallow ones of preserving the water at a more uniform temperature, neither too warm in summer nor too low in winter as to permit of freezing.

Clarification and limited purification of water by subsidence appear to have been known to and practised by the Romans; indeed the piscinæ which have been described by archæologists as filtering places, appear to have been subsidence tanks of special and ingenious construction; and we learn that they were not always successful, but that turbid water was delivered in the Imperial City during times of flood.

At St. Petersburg the waters of the river Neva are clarified, and rendered purer, by a special process, the water being caused to fall in successive cascades each of a couple of feet, on to wire gauze. The gauze soon becomes covered with a black scum, although the water before this treatment is apparently clear. The water of the Neva is a marsh-land water; and the scum is supposed to be formed by the combined effects of 'flocculation' and oxidation of the organic constituents of the river-water ('Proc. Inst. Civ. Engineers,' xxvii. p. 46).

FILTRATION

The clarification of a town water-supply is usually supplemented by filtration; and its purification is also to a certain extent effected by the same means. We shall consider filtration on a large scale as carried out with large supplies, and domestic filtration, i.e. the local filtration of relatively small quantities of water in habitations.

On a large scale, water, after treatment in subsidence reservoirs, is nearly always, in this country at least, filtered through sand and gravel. No great success has attended the attempts to substitute other materials for these, or as a supplement to sand and gravel. It must not be supposed that sand acts solely as a mechanical strainer; for it is also an agent in achieving the oxidation of organic matter, either by the air contained within its pores, or more probably by the condensation of oxygen on its surface; for all finely divided solid substances have this power of condensing oxygen. In this condensed state, oxygen is well known to be peculiarly active in bringing about oxidation. Of this power charcoal in a minute state of division is a striking instance. Vegetable charcoal has the power, when ignited and

plunged into oxygen, or even into air, of absorbing several hundred times its volume of the gas, and then becomes an intense oxygenant.

As ordinarily constructed, a filter-bed may be regarded as a U-shaped tube, with a long and a short limb, the longer limb, some ten feet in length, being represented by the bed of filtering material *plus* the superposed unfiltered water. The filtered water (effluent water) collects in what may be regarded as the shorter limb of the tube. The water is forced downwards through the filtering material by a head or pressure of water represented by the difference in level of the water in the two limbs of the apparatus. The filtering medium may consist of a stratum of fine clean sand, two feet in depth, followed by eighteen inches of screened gravel of various sizes, the finest being at the top and the coarsest at the bottom; and below this there may be thirty inches of broken stones of two sizes, the smallest size at the top. Thus the water in its passage downwards meets successively with filtering material of progressively increasing size as to its particles and the magnitude of the interspaces. The topmost layer of fine sand is the real filtering medium.

The New River Company's filter-beds are constructed, from below upwards, of six inches of bricks, followed by a similar thickness of gravel, and on the top of this a layer of sand thirty inches deep; and the water is usually allowed to stand to a depth of five feet on the top of the filter-beds. The water percolates downwards at about the rate of six inches per hour; or half a cubic foot, equal to $3\frac{1}{3}$ gallons, passes through each square foot of surface per hour, or 74 gallons per diem, equivalent to 136,000 gallons nearly per acre per hour. This rate is thought by some authorities to be excessive, and they would put the maximum permissible rate at 60,000 to 100,000 gallons per acre per hour, or from three to four and a half inches of downward progression per hour.

As has been already stated, it is the uppermost layer of sand which is the effective purifying material; and this layer in contact with the main body of water to be filtered soon becomes foul and clogged, so that the filter-bed has to be run dry and its upper surface scraped pretty frequently, when a fresh surface being exposed the filter is again set in action. Thus the filter-beds are worked intermittently, some of the beds being always undergoing renovation. After a certain quantity of the sand has in this way been removed by successive scrapings, fresh sand must be placed on the filter.

Such filters as have been described, are effectual in removing all suspended matters from the water, if this be not forced through the filter-beds too rapidly by excess of pressure. The rate will vary according to the character of the water to be operated on. It is obvious that a slightly turbid water may be filtered with safety at a much greater rate than a highly turbid water. Filtering beds vary in size from half an acre, or even less, up to four acres. The depth of water over the filtering material may be four or five feet; but the actual head or pressure of water—the difference of level between the height of the water in the two limbs of the U-tube—must be made to vary: when the filter is clean a foot or less of head or pressure will suffice; but as the filter becomes clogged by use, a greater pressure must be used, else the water will not pass through the filter with sufficient rapidity. It must be borne in mind that the slower the filtration the more effective will it be in purifying the water. The aim of the engineer is of course to filter just so much water per hour as is consistent with the desired degree of purity. The rule is that each vertical inch of water passing represents half a gallon nearly per square foot of surface, or 22,700 gallons per acre per hour, approximately—the requisite supply for about 600 people.

In variable climates deep filter-beds are best, so as in winter to have a large body of water so as to avoid freezing; and the edge of the water must be kept free from ice, in order to obviate the outward thrust of this if it forms, else the masonry of the walls of the filter-beds would be endangered. Deep filter-beds have the additional advantage of keeping the water cool in summer; but they have also the disadvantage of greater liability to stagnation than those which are shallower.

The filtered water should be stored in covered reservoirs, so as to avoid contamination with dust; and reservoirs near towns are usually required by statute to be effectively covered. It is desirable also to distribute the water from the reservoirs through closed pipes rather than through open conduits.

Filtration through sand alone undoubtedly does more than simply remove suspended matters and living organisms: organic matters are oxidised, and the water is thus much improved not only in appearance but also as to its purity. Attempts have been made to further purify waters by using filter-beds charged with charcoal, spongy iron, partially oxidised scrap iron, &c.; but all these have in this country been abandoned in practice. They are too costly, and require too frequent renewal to admit of their profitable adoption; and moreover if a fairly pure water-supply be adopted (and none other should be used) the use of any better filtering material than clean, well-washed sand is not called for. The attempted purification for drinking purposes of organically polluted water ought to be deprecated. An essentially bad water cannot be turned into a good water by any practically available process of simple filtration.

The Porter-Clark process is an admirable one for removing excess of temporary hardness, and the carbonate of calcium deposited in the process carries down with it organic matters, so that the filtered water is fairly soft, clear, and of a fine blue tint when viewed in thick layers.

Household Filtration

Under the head of household filters may be placed the innumerable filters which have been introduced for filtering water immediately before its use in houses, factories, and like establishments.

Where water, efficiently filtered on a large scale, is distributed direct from the storage reservoirs on the constant system, the writer is of opinion that it is as a rule best to draw the water direct from the main supply-pipe, and to use it without further filtration. But where the water is supplied on the intermittent system, and is consequently stored in household cisterns, it is often desirable to filter it before use. Also in times of epidemics it is desirable for safety to boil drinking water and filter it before use. More often than not, perhaps, a drinking water is rendered less pure by ordinary filtration; and nearly always household filters are placed in most undesirable situations, such as near sinks, in pantries, near kitchens, &c. i.e. in impure atmospheres. Under these conditions the water is apt to absorb gases and vapours which give it an unpleasant flavour; and this is more particularly the case when the water is boiled. Boiling water when cooled in an impure atmosphere very quickly absorbs gases and vapours; and thus it is notorious that water which has been boiled is not only very often vapid but positively nauseous in flavour.

Notwithstanding these disparaging remarks as to domestic filtration, it must be admitted that there are circumstances under which a water must be filtered in order to render it wholesome. Marshy water, taken by the soldier on the march from doubtful or obviously impure sources, and soft peaty waters which have passed through leaden pipes, must be filtered.

The varieties of filtering media which have been used are innumerable; but it may be stated generally that these display the skill of the inventor and patentee to excess, and that most of them are of comparatively little use with regard to real effective purification.

Fresh burnt *animal charcoal* is perhaps the best of all filtering media, and filters chiefly constructed of this material should always be used for lead-polluted water-supplies. The experience of Mr. A. H. Allen with the Sheffield waters is to the effect that no other substance is nearly so efficacious as animal charcoal for removing lead from water. In Maignen's 'Filtre Rapide,' animal charcoal and asbestos cloth are used. *Vegetable charcoal* is far less efficacious than animal charcoal as a purifying agent. *Seaweed charcoal* is said to be superior to ordinary vegetable charcoal in this respect. The great defect of all forms of charcoal filters is that they speedily become inefficacious, and the charcoal must be frequently renewed or re-burnt, else the fouled charcoal will, as Dr. Frankland has shown, actually increase the amount of organic impurity in the water. Block-carbon filters (moulded carbon blocks) do little more than remove gross suspended particles, are mostly useless, and should not be used except when no better filter can be found, as by the soldier on the march, to whom a small suction filter is invaluable.

Sponge is now not often used. It merely removes suspended particles, and soon clogs and becomes foul. Sponge filters require constant attention, and frequent cleaning and renewal. *Asbestos* is a much better material, and can easily be re-burnt. It acts only mechanically.

Porous stone, pumice, and ground slag (Chamois Filter) act merely as mechanical filtering media; and filters constructed of these materials are not very serviceable.

Spongy iron (Bischoff's filter), *magnetic carbide*, *silicated carbon*, and *carbonised ironstone* are useful filtering materials, which act mechanically as strainers, as oxidisers by surface condensation of oxygen, and also perhaps by electrolytic action.

Carferal or *carbolite* (Creuse's Service Filter) is an efficacious filtering medium. It appears to be made from clay with some iron and carbon. Its preparation is somewhat of a secret. Creuse's filter is a good simple one, and easily cleaned.

The Chamberland-Pasteur Filter is perhaps the best of all domestic filters. Its construction is very simple, for it merely consists of a tube of fine unglazed biscuit porcelain, which may be screwed on to the service tap, when the pressure of the water will force the fluid through the pores of the porcelain, and a fairly rapid rate of filtration results. It is most efficacious in removing even the finest suspended particles, for even the bacilli of anthrax are by it effectually removed from water. This filter acts purely mechanically. It appears to be inefficacious for the removal of lead from waters. The surface of the porcelain tube in a short time becomes covered with a slimy coating, even when an apparently clean water is filtered. This coating is, however, readily and quickly removed by removing the tube and brushing it, or by washing it with hydrochloric acid.

QUALITY OF WATER

In their Sixth Report the Rivers Pollution Commissioners, 1868, remarked that in respect of wholesomeness and general fitness for drinking and cooking their researches led them to the following classification of waters in the order of their excellence, and founded upon their respective sources:

Wholesome	1. Spring-water 2. Deep well-water	Very palatable.
	3. Upland surface water	Moderately palatable.
Suspicious	4. Stored rain-water	
	5. Surface water from cultivated land	Palatable.
Dangerous	6. River-water to which sewage gains access. 7. Shallow well-water	

And they urged that preference should always be given to spring and deep well-water for purely domestic purposes, over even upland surface water, not only on account of the much greater intrinsic purity and palatability of these waters, but also because their physical qualities render them peculiarly valuable for domestic supply, since they are almost invariably clear, colourless, transparent, and brilliant; qualities which add greatly to their acceptability as beverages, whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer, and prevents them from freezing readily in winter. Their inestimable value to communities in these respects is, however, in some degree neutralised, as regards temperature, when they have to be stored, and too often the quantities available are inadequate to supply the needs of large communities, and too costly. Hence we find that for large towns upland surface water-supplies are now being largely adopted; as witness Glasgow from Loch Katrine, Manchester from Lake Thirlmere, and Liverpool from Lake Vyrnwy. Often, too, it is desirable, and more especially in the case of a manufacturing population, to have not only an organically pure, and a palatable, but also a soft water-supply; and here the advantage of an upland surface water becomes manifest, as appears from the following classification, according to the Rivers Pollution Commissioners, of natural waters, in the order of their softness:

1. Rain-water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river-water.
5. Spring-water.
6. Deep well-water.
7. Shallow well-water.

The geological strata through which a spring or deep well-water has percolated will greatly influence its palatability. Whilst surface waters are often vapid and tasteless from a deficiency of carbon dioxide, or have a peaty bitter flavour, in percolating through deep rocky strata organic matters are oxidised, and such waters are often highly charged with carbon dioxide gas, which renders them brisk and palatable. The waters drawn from deep artesian wells in the Thames basin are often deficient in oxygen and faintly opalescent. Some also contain traces of sulphuretted hydrogen, and need exposure to the air to render them palatable; whilst others, again, when stored, become impregnated with confervoid growths. The spring waters of the magnesian limestone formation are not only excessively hard, but contain such a proportion of magnesian salts as, in the opinion of most sanitary authorities, renders them unfit for drinking purposes. A pure magnesian water may, nevertheless, it is thought by many sanitarians, form a good water for domestic use. The experiences of Sunderland and of Bristol are not unfavourable to the use for drinking purposes of magnesian waters.

The deep well-waters of some of the beds of the New Red Sandstone are rich in sulphate of calcium, as well as in chalk, and, though palatable, are excessively hard.

Of far more importance than its salinity and hardness is the freedom of a drinking-water from contaminating injurious metals, such as lead, copper, and chromium. Salts of barium, which in excess are poisonous, and in small quantities medicinal, are found in some mineral waters—e.g. those of Harrogate. The influence of barium compounds in minute quantities is but little known, and of but little interest to the sanitarian.

Copper compounds are injurious when habitually ingested, and hence waters containing this metal ought to be rejected.

Chromium salts, especially chromates, act as virulent poisons even when taken in small quantities. These compounds are but rarely met with in waters, and exclusively in mining districts.

Chalybeate waters—those containing iron salts—are nauseous, stain linen, and are unfitted for drinking and washing purposes. All natural waters, perhaps, contain some small trace of iron compounds, but not sufficient to communicate a perceptible flavour to the water. Chalybeate waters should, if better water is procurable, be rejected as unfitted for domestic supplies.

Of vastly more importance is the *contamination of waters by lead.* Though the corrosive action of certain waters upon lead has long been known, and its influence recognised, and although many experimental researches have been instituted with the view of elucidating this action, our knowledge of the matter is still confessedly incomplete. Pure water, deprived of gases, has little or no action on lead; when, however, the water contains oxygen the lead is rapidly corroded and dissolved; the solvent action being hastened, if not even started, by the presence of traces of carbonic or other acid. The lead dissolved appears to be in the form of a hydrate (hydrated oxide of lead). On exposure to air, the dissolved lead is soon thrown down in the form of the almost insoluble hydrocarbonate (basic carbonate of lead, or white lead). The deposit is very finely divided and has very little coherence, and hence when the deposit forms on the surface of the metal—as, for instance, when there is simultaneous oxidation and precipitation of the lead on the surface of a leaden pipe—the hydrocarbonate does not protect the metal beneath from the further corroding action of the aërated water. Hence pure rain-water and distilled water corrode lead with great rapidity. If a few grains per gallon of sulphate of calcium be introduced into such a water, an adherent and coherent thin grey film of a lead compound quickly forms on the surface of the metal, and the water subsequently takes up a quite inconsiderable amount of lead; and thus the metal is preserved from further corrosion. Other earthy salts have a similar effect. Some saline bodies, such as nitrate of ammonium—a constituent of ordinary rain-water—increase the solvent action of water upon lead. Carbonic acid diminishes the corrosive action of waters on lead, probably by forming the insoluble hydrocarbonate; but an excess of carbonic acid, under increased pressure, increases the solvent action of the water (Muir). Hence aërated water ('soda water') is exceedingly liable to become contaminated with lead.

It has been asserted that carbonate of lead, like the carbonates of calcium and magnesium, is more soluble in excess of carbonic acid than in water, and that a bicarbonate of lead is formed when lead is present in solution in a water containing excess of carbonic acid, and experimental proof of this action has been furnished.

Among the many substances that have been credited with increasing the solvent action of water upon lead are—carbonic acid; free mineral acids; carbon acids, the product of the decay of vegetable matters, and especially peat; organic matters; nitrates and nitrites; and chlorides—a sufficiently extended list. Among the substances which have been stated, on the other

hand, to retard corrosion and solution are carbonic acid, carbonate of calcium, sulphate of calcium, phosphates, and silica, or rather dissolved silicic acid (Odling, Crookes, and Tidy). Dr. Tidy asserts that waters which contain less than half a grain per gallon of dissolved silica act freely upon lead, whilst those which contain more than half a grain of silica per gallon do not—except, perhaps, under exceptional circumstances—dissolve lead to any appreciable or injurious degree; and he, together with Drs. Odling and Crookes, have proposed to artificially impregnate waters with silica when they contain such a deficient quantity as to render them operative. They advise that such deficiently silicated waters should be run over broken flints, or a mixture of flints and chalk, or limestone, and it has been asserted that the flints are obviously dissolved during the process. In opposition to this, the writer, Dr. Dupré, and Mr. A. H. Allen, have found that the soft waters (*e.g.* those of Sheffield), which act freely and injuriously on lead are, in many instances at least acid in reaction; and that the acidity may be due to the presence of fixed organic and inorganic acids, or both. The organic acids are due to the oxidation of peat. The inorganic acid may be sulphuric, arising from the influx of a ferruginous water containing a ferrous salt. On exposure the ferrous salt oxidises and splits up into an insoluble basic ferric salt, and free sulphuric acid or an acid sulphate. Such waters, when run over a weir or along a conduit, composed of broken soft limestone or chalk, have their acidity neutralised; they take up a small quantity of carbonate of calcium, and acquire additional hardness, corresponding to the excess of chalk dissolved beyond that consumed in neutralising the free acid. This extra hardness may amount to a degree or two per gallon. The soap-destroying power of the salts of calcium, formed by the action of the fixed acids, is not greater than that of the free acids neutralised.

It must be admitted that the whole subject of the action of waters upon lead, and its prevention, stands in need of further elucidation and research; and although we may in some particular instances be able to account for the action of water upon this metal, the same explanation entirely fails in other cases. Thus the writer of this article has found that whilst the addition of an alkaline silicate of sodium to distilled water will prevent the corrosion of lead by the water, the same addition in other cases, under other conditions, may fail as a preventive. Again, it is not only soft waters exclusively that act on lead, for many hard waters will have the same effect. Neither the silica theory, nor the acid theory, of the action of waters upon lead, accounts for the whole facts known; and of two apparently similar waters as to constituents, one will act vigorously upon lead, whilst the other may have little or no effect in dissolving the metal.

Mr. W. H. Power, having regard to the observed influence of acidity on the solvent actions of soft moorland waters on lead, offers the suggestion that the 'inscrutable behaviour' of these waters in regard to plumbo-solvent ability may be related to the agency, direct or indirect, of low forms of organic life. This suggestion, no doubt, has as its basis the circumstance that certain bacteria have been found experimentally to produce acid changes in the culture media in which they have been grown; but the results hitherto obtained with the Sheffield plumbo-solvent waters are mostly negative (Reports of the Medical Officer of the Local Government Board for 1887 and 1888, pp. 280 and 453 respectively).

The experience of Sheffield, Keighley, and other English towns has been repeated at Dessau in Germany. The water-supply of this town was free from lead before distribution, yet 92 cases of lead-poisoning occurred within a short time, and it was then found that the water took up lead from the

house-pipes; and the water first drawn after standing in these was found to contain 0·3 grain of lead per gallon. It was also found that when tin was introduced into the pipes, the solvent action of the water on the lead was increased. It was finally concluded that the mischief was due to the want of hardness in the water itself, which was only equal to 3° to 3°·4 of Clark's scale. By increasing the hardness to 6° or 7°·2, by the use of powdered limestone, the mischief was remedied. It is stated that this result was due, not to the increase of hardness, but to the removal of carbonic acid, the absence of which rendered the water incapable of acting on lead.

The processes for preventing access of lead to the stomach through the medium of drinking water may be divided into three groups, namely: (1) processes for preventing the water from dissolving lead; as an example of such treatment, we may mention the addition of lime to the water, whereby free acids are neutralised, and their solvent action upon lead avoided; (2) processes for avoiding contact of the water with lead; for example, by using slate or galvanised iron cisterns, and glass-lined or tin-lined pipes; and (3) processes for removing lead from the water after it has been dissolved thereby; as examples of which filtration through compressed carbon, sand, &c. may be instanced. Mr. Eaton estimated the cost of treating the Sheffield water so as to avoid any solvent action upon lead at 20,000*l.*, with an annual expenditure of 350*l.* to maintain efficiency. The Sheffield water contains free acid, and limestone has been found a preventive. Clearly it is more satisfactory to strike the evil at its root by treating the water in such a way before it gains access to the poisonous metal as to prevent it from being contaminated thereby, than to trust to measures for preventing contact with the metal, or for removing it after it has been dissolved in the water.

EFFECTS OF HARDNESS OF WATER USED FOR DRINKING AND OTHER DOMESTIC PURPOSES.

Very different opinions are held as to the injurious or non-injurious effects of the use of hard waters for domestic supplies. Up to some fifty years ago scarcely a suspicion appears to have been entertained that such waters might injure health, however unpleasant their use might be for detergent purposes. The researches of the late Dr. Clark, of Aberdeen, on the hardness of water, its estimation, and above all, the introduction of his now widely-known process for softening waters, drew attention to the subject; so that in 1850 the General Board of Health arrived at the sweeping conclusion that whilst 'Thames water (of about 14° of hardness) taken up beyond the influence of the metropolitan drainage, and filtered, may be used without injury to the public health and may be employed temporarily until other sources can be laid under contribution; we advise that Thames water and other water of like quality as to hardness, be as early as practicable abandoned' (quoted in 'Report: Royal Commission on Water-supply,' p. xxiv 1869); and, 'that the presence of lime and other mineral matter deteriorates the wholesomeness and value of the water for the purpose of drinking' (*ibid.* p. lxiii.). This Report was, however, not endorsed by the subsequent Scientific Commission of 1851, consisting of the three eminent chemists Graham, Miller, and Hofmann, appointed to consider it; and they went so far as to enunciate an opposite view. They said (p. lxiii.): 'It may be safely asserted that no sufficient grounds exist for believing that the mineral contents of the waters supplied to London are injurious to health. No reasonable doubt, indeed, can be entertained of their salubrity. The shallow

well waters of London vary from 32° to 80° of hardness, yet these waters have never been pronounced unwholesome (i.e. on account of their mineral constituents.—Ed.). . . . The only observations, from which an interference of lime in water, in deranging the processes of digestion and assimilation in susceptible constitutions, has been conjecturally inferred, have been made upon waters containing much sulphate of lime and magnesia.'

Dr. Letheby considered a moderately hard water best for drinking purposes, and for the general supply of cities. Mr. Thomas Hawksley, the engineer, states from his vast personal experience, that there are quite as many fine-raced people living in hard-water districts as there are living in soft-water districts; and that quite 80 per cent. of the whole surface of the globe yields hard water. Sir John Simon, Dr. Miller, Dr. Frankland, Dr. Odling, and Sir Benjamin Brodie, have all expressed their opinions that hard waters—up to 20° of hardness at least—are not injurious to health. Dr. Edward Parkes was of opinion that a hardness of over 10° or 12° might be injurious.

There is no doubt that medical opinion has undergone some change as to the alleged unwholesomeness of hard waters; and it is now generally accepted that excessively hard waters are injurious to the digestive processes, though proof of this is difficult; and the conclusion has been doubted. Goitre and glandular swellings, as well as the prevalence of urinary calculi in certain districts, are associated with the use of hard waters. All are agreed that where the hardness of a water is due to the presence of carbonate of calcium, and to a lesser degree of carbonate of magnesium, i.e. when the hardness is temporary or removable, little harm ensues; but that when the hardness is permanent, and due to the presence of the sulphates, nitrates, and chlorides of calcium and magnesium, the dietetic value of a water is greatly impaired. How far this opinion is based upon a solid basis of facts is at least uncertain. The waters of the valley of the River Trent, and very many of those derived from wells and springs in the New Red Sandstone formation, are intensely seleniferous, i.e. abound in sulphate of calcium, and yet are not generally considered harmful. Some of our town supplies, as e.g. those of Bristol and Sunderland, are very hard, the water supplied to Sunderland containing magnesia and sulphates, the equivalent of 14 grains anhydrous and 28 grains crystallised sulphate of magnesium per gallon; yet the Medical Officer of Health has not been able to trace any inconvenience to health, much less disease, to its use, and it is believed to be a good wholesome water, though having a hardness of 25°.

As has already been stated, goitre and cretinism have been attributed to the habitual drinking of excessively hard water. Eminent medical authorities have, however, dissented from this conclusion; very hard waters are, it is true, found as a rule in districts where goitre prevails; but the water-supply is only one among many conditions shared by such localities in common; and it is alleged that of the inhabitants of two sides of a valley with practically identical water-supplies as to hardness, those on one side of the valley will suffer from goitre, whilst those on the other side will be exempt from the disease.

For most culinary purposes a hard water is objectionable, and the presence of calcium salts is said to harden the fibre of meat during boiling. Sulphate of calcium, too, when boiled with leguminous seeds, is asserted to form hard indigestible compounds with the legumin which they contain. But the evidence as to this is not very conclusive. Generally a chalky water is quickly and greatly softened by boiling, or by heating it simply to the boiling point; the carbonate of calcium held in solution by excess of carbonic acid being pre-

cipitated in consequence of the escape of carbon dioxide gas at the boiling temperature. The Chemical Commission of 1851 ('Quart. Jour. Chem. Soc.' vol. iv. p. 388, 1852) found that the water supplied by the New River Company to London, having a total hardness of 14° to 15° and a permanent hardness of about 2°, when drawn on six different occasions from the fixed boiler of a kitchen range, had a hardness of 5°·4, 4°·9, 4°·1, 4°·1, 4°·9, and 5°·3; the average being 4°·8, or one-third of the original amount. In tea-making, hard water is thought by connoisseurs to yield a more delicate infusion than soft water, and is hence preferred. A soft water, on the other hand, yields with tea a darker and bitter infusion, and is hence more esteemed for the purpose by the lower orders, who desiderate 'strength' of tea. The chief difference in this respect between a hard and a soft water is that when a hard water is used a longer time is required for the infusion of the tea.

For washing and for manufacturing purposes a soft is undoubtedly preferable to a hard water, except in brewing. The relative values of waters for washing purposes is a much more important consideration for a health officer than their utilities for the purposes of the manufacturer. Nevertheless, in towns, the latter cannot, for economic reasons, be altogether disregarded. The Chemical Commission of 1851 (*op. cit.*) stated (and the statement holds good in the present day) that the softer the water the better is it adapted for washing with soap; the earthy salts present causing a definite and calculable loss of soap, which may be taken as amounting, with every gallon of water used in washing, to 10 grains of soap for each degree of hardness of water. But such data are not alone sufficient for calculating the saving of soap effected by the use of a soft in preference to a hard water; for soap is used in washing not merely in quantity sufficient to soften the water, but in excess to act as a detergent. The data to determine the problem how great is the proportion of soap lost in softening, compared with the proportion profitably used for washing, are not easily obtained. It has, however, been ascertained that in the washing of woollens 2 oz. of soap per gallon is required; and in the soaping of dyed goods—a process analogous to common washing—0·45 oz. only per gallon. With boiled Thames water of 5° of hardness, these quantities would be increased to 2·11 and 0·56 oz.; or the quantities of soap required with a soft water are increased by 6 and 25 per cent. respectively. When cold water of 16° of hardness is used, the quantities of soap consumed in washing will be 0·32 oz. per gallon in excess of that used with soft water.

When soda is used in addition to soap, as in ordinary laundry work, the loss of soap is much less, since the soda (carbonate of sodium) precipitates the calcium salts in a form which prevents the destruction of soap.

The money loss involved in the use of hard water has been much exaggerated. The difference between the use of water of 2° and one of 14° of hardness is about 128 grains of yellow soap per gallon, or $1\frac{3}{4}$ oz. per 6 gallons, 6 gallons being the ordinary consumption of water per head per day for washing purposes; it being assumed that the water is used cold. The money value of this amount of soap is 0·04*d.*; whilst the cost of softening 35 gallons of water—the daily supply per head in towns—by the Porter-Clark process is 0·012*d.* only. The difference is equal to rather more than $10\frac{1}{4}$*d.* per head per annum.

The case against the use of hard water was ably put by the Chemical Commission of 1881 (*op. cit.*), who stated that it is in the more careful washing for the upper and middle classes that the advantages of soft water become fully sensible; for when a hard water is heated the carbonate of calcium is precipitated on the linen, carrying down with it the colouring

matter of the dirty water, and producing stains which there is the greatest difficulty in afterwards removing from the linen. The colouring matter from the water is thus indeed fixed upon the cloth by the precipitated calcium salt with the tenacity of a mordant. The evil of the hardness of the water is also aggravated by the flood tinge of chalky river waters. The Commissioners further stated that the saving of soap by the use of soft water is most obvious in the washing of the person; and for baths soft water is undoubtedly most agreeable and beneficial. Its superior efficiency to hard water in washing floors and walls is calculated also to promote greater cleanliness in the dwellings of all classes, both within doors and externally; whilst in the occasional domestic washing of linen, the smaller preparation necessary for washing in soft as compared with hard water, the saving of soap, and the more easy and agreeable nature of the operation, make a supply of soft water in a high degree desirable. The saving of labour is also considerable, and tends to promote cleanliness.

At a later date the Royal Commission on Water Supply, 1869 ('Report,' p. lxxi.) thus fairly summarised the arguments for and against hard and soft waters as public supplies for London:—

'There is no doubt that the evidence is conclusive and cogent as to the great advantage of soft water over hard for washing, and, with some few exceptions, for general manufacturing purposes; and if we were treating of the supply of a town like those in the manufacturing districts of England, where large quantities are required for these purposes, the objection to the present supply (to London) would assume a more serious aspect. But the amount of manufacturing industry in the metropolis, of a kind to demand a large supply of soft water, is exceedingly small in proportion to the population, and it must be recollected that the softening influence of boiling largely diminishes the evil. To these exceptional cases, also, the softening process of Dr. Clark would be easily applicable.

'There is no doubt, also, that in personal ablutions and washing generally the use of soft water is more pleasant and economical, but we think the latter advantage has been much over-estimated. The soap is usually applied out of the water, and therefore it is with the small quantity of water adherent to the object washed that we have to deal, and not with the total quantity used for rinsing to remove the soap. It is certain, however, that when a soft water or rain-water can be obtained for these purposes it will always be preferred.

'On the whole we cannot see that the advantages of soft water . . . . are of sufficient importance to justify going to a great distance to obtain it, in place of the ample supply near at hand.'

To this the writer would add that the greater danger of lead contamination, often introduced by the adoption of a soft and slightly acid water-supply, may far outweigh, from a hygienic point of view, the disadvantages resulting from the use of a water of moderate hardness.

There is another aspect of the question of soft *versus* hard water which, all-important to the manufacturer, is not without an important bearing upon domestic supplies for a highly civilised and luxurious people. When a chalky water is boiled, we have said that carbon dioxide is expelled and carbonates of calcium and of magnesium are thrown down. Sulphate of calcium, however, remains in solution if the water be boiled under ordinary atmospheric pressure; hence the deposit, or 'fur,' which in household boilers is mostly composed of carbonate of calcium, and is soft, pulverulent, and for the most part easily detached. But sulphate of calcium has its maximum solubility at 95° F., at which temperature a gallon of water is capable of retaining

in solution 178 grains of sulphate of calcium. But as the water becomes more saline by evaporation, the sulphate of calcium becomes less soluble. The same result ensues if the water be heated under pressure much above 212° F. (100° C.) Sulphate of calcium is quite insoluble in a boiling solution of salt (brine) of sp. gr. 1·033, and in boiling water at a temperature of 284°–302° F. (140°–150° C.) Hence the difficulties involved in the distillation of sea-water, in the use of sea-water in marine boilers, and in the use of water containing sulphate of calcium in boilers under pressure. Under these circumstances the hard furs which form on heating the water consist chiefly of sulphate of calcium.

The Rivers' Pollution Commissioners, in their sixth report, thus classify water according to their softness: 1. Rain-water; 2. Upland Surface water; 3. Surface water from cultivated land; 4. River-water; 5. Spring-water; 6. Deep well-water; 7. Shallow well-water.

The following, according to the Commissioners, are the chief British formations which yield, as a rule, soft waters: 1. Igneous; 2. Metamorphic; 3. Cambrian; 4. Silurian (non-calcareous); 5. Devonian (non-calcareous); 6. Millstone Grit; 7. Non-calcareous of the Coal-measures; 8. Lower Greensand; 9. London and Oxford Clay; 10. Bagshot Beds; 11. Non-calcareous gravel.

On the other hand, the following geological formations almost invariably yield hard waters: 1. Calcareous Silurian; 2. Calcareous Devonian; 3. Mountain limestone; 4. Calcareous rocks of the Coal-measures; 5. New Red Sandstone; 6. Conglomerate Sandstone; 7. Lias; 8. Oolites; 9. Upper Greensand; 10. Chalk.

POLLUTION OF WATER BY ORGANIC MATTERS

The pollution of water-supplies by solid and liquid refuse, such as sewage, slop-water, &c., is all-important from the health point of view. The facts, so far as they are known, relative to the pollution of water-supplies by soakage of filth are as follows: Sewage, when deposited on the surface of an ordinary cultivated soil, percolates slowly or quickly into the subsoil, according to the less or greater porosity of the soil. Whilst percolating it becomes nitrified, through the agency of organisms which have recently been identified ('Trans. Roy. Soc.' 1890, p. 107). According to Mr. Warrington this nitrifying action is chiefly exercised in the more superficial layers of the soil, the action practically ceasing at 18 inches below the surface. If the organic matter is in excess, or if the soil be persistently swamped with sewage, nitrification ceases. The nitrifying process renders the nitrogenous matters harmless and fitted for the needs of growing plants, which absorb and utilise the nitrates. When sewage is discharged in excessive quantities on the surface of a porous soil, it quickly percolates through this until it meets with an impervious stratum which arrests its downward course. A shallow or surface well sunk into the porous soil will draw no water until it reaches the stratum of underground water. Into this the liquid soaking from leaky sewers, drains, and cesspits will find its way more readily than the surface water. When water is pumped from such a well the level of the water in this is depressed, and so also is the level of the underground water in its neighbourhood, and assumes the form of a hollow inverted cone, so that any soakage through the soil of liquid filth, or from a drain or cesspool, will inevitably be drawn by the afflux of fluid, according to the laws of hydrostatics, towards the bottom of the cone—i.e. towards the well. The distance through which the hollow inverted cone will extend or

make itself felt will vary according to the greater or less porosity of the soil, and may extend to from 15 to 160 times the depth of the cone. In other words, if the level of the water in a shallow well be reduced by pumping, say 2 feet, water will be aspirated into the well from a distance of $15 \times 2 = 30$ feet as a minimum, to $160 \times 2 = 320$ feet as a maximum. The set or current of the underground water in the neighbourhood of a pumped well must, indeed, always be towards the well; and it is by the suction exerted on cesspools situated in proximity to wells that they are emptied when these are pumped. Hence, in one sense, the more a well is pumped the greater its liability to contamination from neighbouring sources of pollution. The action of wells in use may sometimes greatly divert the course of underground water, which but for the action of wells would always be towards a lower level and towards a stream. The course of underground water is, indeed, precisely like that of surface water—towards the lowest available level; only the slope or declivity of underground is less steep than that of surface water, in consequence of the greater retarding influence of friction in its passage through the subsoil.

For the reasons just now assigned, a surface well can never be safe, however well its sides are cased and made impervious, if there is any pollution of the soil within the distance to which the inverted cone already described extends. Contaminated water will be drawn into the bottom of the well. The only real protection is to sink the well through the first impervious layer of soil, and to cement the sides throughout to a point below the impervious stratum, so as to draw water from the deeper strata, and to protect this water from the more superficial polluted surface water. This plan is too commonly not adopted because an abundance of water is reached before the first impervious stratum of soil is reached, and at a small depth. It is not infrequently found, also, that when the impervious stratum is penetrated the water, previously abundant, is lost; and then the only plan is to carry the well downwards till at a greater depth water is again found. If such a supply is reached it may be expected, if not too saline, to be abundant, little liable to seasonable variations as to quantity, quality, and temperature, and organically pure. Very deep well-waters are, nevertheless, often deficient in aëration, or rather oxygenation, as is well seen in the deep artesian well-waters in and around London, these being sometimes almost destitute of dissolved oxygen.

SELF-PURIFICATION OF WATER

The so-called self-purification of water is, strictly speaking, a misnomer, for in all instances where self-purification occurs the purification is effected by some other agency, except perhaps in one case—that of the purification of a water by subsidence, or the separation of solid suspended particles by simply allowing the water to come to rest. But in even this case the separation of solid particles achieves a further result, for dissolved organic matters are in some way carried down with the deposited mud. A striking instance is the purification of the waters of the river Rhone during their passage through the Lake of Geneva. The turbid and organically polluted water enters the head of the lake, having much the appearance of road-washings, and the clarified and purified water is seen to issue from the lake at Geneva as a beautifully pellucid and magnificently blue stream (see p. 250, *ante*).

Waters are also said to be purified by dilution. It is doubtful whether

this purification ever takes place, except in so far as an impure water, by admixture with a purer water also well aërated, is furnished with the oxygen necessary for the destruction of impurities; nor must it be forgotten that when a relatively small quantity of a polluted liquid is mixed with a large quantity of water of moderate purity, the added impurity may not increase the impurity of the latter to such an extent as to render its assured detection possible to the chemist.

Dr. Frankland and the Rivers' Pollution Commissioners, in their celebrated 'Sixth Report,' have thrown doubts on the self-purifying power of streams through the agency of free atmospheric and dissolved oxygen; but this position has been successfully contested by Odling, Letheby, Tidy, and others; and Dr. Frankland himself has apparently seen his way to modify his previous views as to the oxidising power of dissolved oxygen.

It is probable that the salts of iron always present in natural waters in very minute quantity act in some measure as carriers of oxygen. Putrescent sewage reduces these salts to the lower stage of oxidation of ferrous salts—e.g. ferrous sulphide; and these, under the influence of dissolved oxygen, become converted into ferric or more highly oxygenated salts, which again give up their oxygen to organic matter, and are again reduced to the state of ferrous salts. However this may be, the writer is convinced that free oxygen is capable of effecting the rapid purification of streams, notwithstanding the adverse laboratory experiments of Dr. Frankland. Some think that iodine compounds, also rarely entirely absent from terrestrial waters, act as carriers of oxygen, by their alternate oxidation into iodates and reduction to the state of iodides.

Ordinary free oxygen, and, still less, atmospheric air, oxidise putrescible organic matters when in dilute solution only slowly in laboratory experiments. Under natural conditions, where water is exposed to an enormous and practically unlimited volume of atmospheric air, the result is apparently different; and it is probable that atmospheric ozone and peroxide of hydrogen may have much to do with the effective oxidation of the nitrogenous organic substance present in the polluted waters of rivers. These oxidising agents can have, however, little or nothing to do with the oxidation of organic matters in the soil, and in the water percolating into the subsoil. Here a different agency comes into play.

The changes which nitrogenous organic matters undergo during their downward passage through the soil are, notwithstanding the extended investigations bestowed upon them by Lawes, Gilbert, Warrington, and others, only imperfectly understood. Under the ordinary conditions of cultivation, nitrogenous manures—animal excreta in fact—rapidly disappear as such, their nitrogen being converted, first into ammonia, and then into nitrates. Nitrification depends upon the presence of an organism, and takes place chiefly in the superficial layers of the soil, and does not extend, as a rule, much below 18 inches below the surface. In a cultivated soil most of the nitrates are absorbed and utilised by growing crops, so that but little nitrate flows away in solution in the subsoil water. It is not known that the water drawn from the subsoil beneath such manured soils is injuriously contaminated, though it is likely that where the soil is excessively manured the water may be unwholesome. It might, therefore, be anticipated, *à priori*, that water taken from greater depths, such as that from shallow wells, would be still less likely to contain injurious impurities. But abundant experience teaches us that the water of shallow wells is peculiarly liable to contain disease-producing impurities, except in those cases where the water supply is protected by an impervious layer of soil, such as clay. Again, wells sunk

to no great depth in a gravelly soil frequently yield an organically polluted water. These differences may be reconciled on the supposition that a well draws polluting liquids rapidly through the superficial and nitrifying layer of surface soil, so that the organic matters pass through large pores and fissures in the soil, and thus escape the agency of those organisms which would otherwise convert the nitrogenous matter into harmless nitrates. This supposition receives confirmation from the well-established fact that the water of shallow wells abounding in nitrates, though usually not decidedly harmful to drink, occasionally gives rise to outbreaks of disease, and that these outbreaks are usually accompanied by a diminution of the nitrates habitually present in the water, and a corresponding rise in the organic nitrogen and albuminoid ammonia.

The enormous extent of purification of streams effected by aquatic animal and vegetable life has been too little appreciated. Where fresh sewage flows from a sewer into a stream the mouth of the sewer becomes the feeding-place of numerous small coarse-feeding fishes, which greedily devour and convert into food for larger fishes the scraps of muscular fibre and other *débris* which would otherwise decompose and pollute the stream. Minute particles of solid organic matter may, and probably do, serve as the food of minuter forms of aquatic animal life, and thus indirectly serve as food for fish. The mud banks of the Thames estuary are the habitat of the finest flat-fish, eels, and molluscs which serve the London market. But putrid sewage-polluted streams are shunned by aquatic animals, and it is known that stinking streams do not readily undergo self-purification—as witness the Thames; though here the saltness of the water below London Bridge may cause the water to have a preservative effect on the molecules of undecomposed and decomposing sewage. To what extent subsidence, oxidation, and the presence of animal life are respectively potent in bringing about the purification of our rivers is at present quite unknown.

Nor must the beneficent effects of growing green plants be ignored. Such plants, even those of a low type, are capable under the influence of sunlight of effecting vast changes in the character of a water. The cleaning out of tanks and ponds, so as to free them from weeds, has been known to render the water of such reservoirs more impure, by depriving them of a most active agent of purification. The oxygen given off by growing green chlorophylliferous plants is probably like other forms of nascent or atomic oxygen, peculiarly active as an oxidiser; and this furnishing of nascent oxygen may be one of the most valuable agents for effecting the oxidation of dissolved and minutely divided solid forms of organic matter.

Lastly, vegetable matter deposited in the bed of a stream undergoes a fermentative change, and one of the products of this change is marsh-gas, so abundantly liberated on stirring the bed of any muddy ditch. This, then, is another mode by which organic matter may be converted into harmless inorganic forms of matter.

Nitrification—effected by an organism—is not a very active process in running water, and it is a mode of changing organic into inorganic matter, more effectively going on in soils than in rivers and other water-courses.

The probably enormous changes brought about by schizomycetes (bacilli, bacteria, &c.) must also not be forgotten.

Altogether, then, the natural purifying agencies ordinarily going on in streams are in the aggregate enormous, and generally effective.

Dr. Tidy, who is one of the strongest defendants of the potability of river water, even after the influx of sewage, after a review of all the facts, thus summarises his conclusions:

1. That when sewage is discharged into running water, provided the primary dilution of the sewage with pure water be sufficient, after the run of a few miles, the precise distance of travel being dependent on several conditions, the removal of the whole of the organic impurity will be effected.

2. That, whatever be the actual cause of certain diseases, i.e. whether germs or chemical poisons, the *materies morbi* which finds its way into the river at the sewage outfall is destroyed, together with the organic impurity, after a certain flow.

These conclusions were formulated before the bacteriology of specific diseases was developed; but observation appears to show that a flow of 20 miles in a river is not sufficient to destroy the germs of typhoid fever. Dr. Barry, in a recent report to the Local Government Board, expresses his opinion that a flow of 40 miles at least is necessary after an irruption of sewage in order to render the river-water a desirable supply for drinking purposes. He bases his opinion on an outbreak of typhoid fever following an irruption of filth into the river Tees.

EFFECTS OF IMPURE WATER

No one in the present day doubts that epidemics may spread by means of drinking-water, and the surmises of physiologists that this is brought about by specific living germs or spores have within the last few years been confirmed by the actual discovery of the bacilli or bacteria which are the active factors in propagating certain forms of disease. But whether the germs of disease present in drinking-water are the actual direct agents in communicating disease, or whether the chemical products of the active changes involved in the life-history of these germs are the intermediate factors, is not yet altogether determined. There is evidence, however, tending to show that it is in some cases the actual germs or living organisms in water which propagate disease; for waters specifically infected with dejecta, containing minute traces only of organic matter, are capable of spreading a disease. It is highly probable that when a water receives typhoid or cholera germs, these do not multiply in the water, but gradually perish, having no appropriate nidus in which they may develop; but that if the water still containing any such living germs be drunk, a sufficiency of these may be taken into the human body to set up active disease, provided the body be in a fit state for the germs to undergo development. The well-known fact that when typhoid and cholera dejecta are very largely diluted with water they become incapable of spreading these diseases points apparently to the opposite conclusion; but it may be that the usual non-spreading of cholera and typhoid epidemics where the dejecta have been enormously diluted is to be explained by the few germs received by any one individual on drinking the excrement-polluted water. The experiments of Chauveau ('Comp. Rendus,' 1868, pp. 289, 317, and 359; '12th Rep. of Med. Off. of Privy Council, 1869') have shown clearly that it is the solid particulate matter of vaccine and small-pox virus, &c., and not the soluble components thereof, which is concerned in the propagation of these diseases by inoculation. Brieger's more recent researches, and those of Dr. Sidney Martin ('19th Rep. Med. Officer Loc. Gov. Bd.' p. 235) show, on the other hand, that bacteria may produce specifically toxic chemical compounds.

Cholera

That cholera is a disease which, in this country at all events, is or has been largely propagated by means of excrement-polluted water-supplies, is abundantly evident. The experience of London as to cholera is most instructive, and as strikingly put in the '6th Report of the Rivers Pollution Commissioners.' Epidemics of cholera have prevailed in London in the years 1832, 1849, 1854, and 1866. In 1832 a considerable part of London was supplied with water from the rivers Thames and Lea, and the remainder from shallow wells. But at that time the river water could not have been nearly so polluted as subsequently, in consequence of the absence of sewers and the comparative smallness of the population. The death-rate from cholera in 1832 was 3·14 per 1000 of the population. In 1849 the water was drawn from similar sources, except that more water relatively was drawn from the river than from wells. But meantime sewers had been constructed and water-closets were in general use. Hence the river supply of water must necessarily have been much more impure than on the occasion of the cholera visitation of 1832, and the mortality from this disease rose to 6·18 per 1000. In the epidemic of 1854 the mortality was 4·29 per 1000. In 1866 the main drainage scheme of the metropolis had been carried out, and the sewage was discharged into the Thames miles below London Bridge. In this epidemic the mortality fell to 1·8 per 1000. In the cholera epidemic of 1849 in London, it was observed that the population supplied with water from the Thames suffered more and more from cholera according as the water was abstracted from the river at successively lower points. Thus of those supplied with water taken from the river at Kew, 0·8 per 1000 died of cholera; those supplied with water drawn at Hammersmith, lower down the river, perished to the extent of 1·7 per 1000; in the west of London, the water being taken at Chelsea, 4·7 per 1000 died; whilst of those supplied with water abstracted between Battersea and Waterloo Bridge, i.e. in the metropolis, no less than 16·3 per 1000 died of cholera alone. When cholera next visited London, in 1854, the Southwark Water Company still continued to draw its supply from the river at Battersea, close to one of the sewers; and the river was presumptively filthier than in 1849. In Bermondsey, which was supplied with water by the above company, the deaths from cholera in 1854 were greater by 13 per cent. than in 1849—a difference more than corresponding to the increased population. But in the interval of five years the Lambeth Water Company had removed their intake to a point above the tidal lock at Teddington; and it was found on comparing the houses in the same district supplied by the two companies—the pipes of the two companies often interlacing in the same street—that in the houses supplied from the river within the metropolitan area the deaths from cholera were 57·1 per 1000 houses, whilst in those supplied from the Thames above London and the tidal influence the deaths were only 11·3 per 1000 houses. Well might Sir John Simon term this a 'gigantic crucial experiment performed on half a million of people' (Royal Commission on Water Supply, 1869; 'Min. of Evid.' p. 143).

Perhaps a still more striking experiment was made in the east of London, in the cholera outbreak of 1866, by the East London Water Company, which, in the language of the Rivers Pollution Commissioners ('Sixth Rep.' p. 145) distributed 'unfiltered water excessively polluted with sewage,' and which, in the opinion of Mr. Netten Radcliffe, was specifically contaminated with the excrement of the first two patients who died in that year of cholera in the

east districts of London. Now the district of the East London Company, supplied with water from this Old Ford reservoir, was the portion of their district which was the sole area of intense cholera in London in 1866. Again to quote Sir John Simon's words, 'The area of intense cholera in 1866 was almost exactly the area of this particular water-supply, nearly, if not absolutely, filling it and scarcely, if at all, reaching beyond it' (*ibid.* p. 144).

It is not contended that water is the sole agent concerned in the distribution of cholera contagion, but it is certainly one of the chief media for extending the disease.

Perhaps the most instructive and striking instance of the spread of cholera through the medium of polluted water is recorded as having occurred in 1854 around Golden Square, Soho, by means of the Broad Street pump. This district, in which a formidable outbreak of cholera occurred, had a population in 1851 of 42,272, and was not a low-class district. During August 1854 cholera was prevalent in the locality, but not to a serious extent; but on September 1 the disease broke out with fearful violence, and continued till the morning of the 5th, when it began to abate. One of the chief features of this memorable outbreak was its suddenness, and the large number of individuals simultaneously attacked in different parts of the district. The total number of deaths from cholera in September recorded in this limited area was 609, or 14·2 per 1000 of the population. This district contained a public pump—the Broad Street pump; and this pump was the centre of the infected district, for, starting thence, a person walking at a moderate pace in any direction would have gone beyond the limits of the infected area within three minutes. A special examination showed that the water of the well was contaminated by filtration from a cesspool during the time of the cholera outbreak. Though the water of the well was grossly impure, it was in great repute through the neighbourhood for drinking purposes, and was much liked, being cool, sparkling with carbon dioxide gas, and keeping well, in consequence of the large quantity of saline matter it contained. But on exposure to the air for a few hours it lost its freshness, and became offensive in a few days. Dr. Snow was able to show that not only was the outbreak, properly so called, principally confined to near about the pump, but that 61 out of 73 persons who died during the first two days had been accustomed to drink the pump-water; that in the workhouse, where the well-water was not used, the deaths from cholera were only one-tenth of the ratio prevalent in the neighbourhood; that no less than 9 per cent. of the people in a factory where the water was drunk daily died; and that 70 men employed in a brewery in Broad Street, and who never drank the water, all escaped cholera. Investigation of numerous individual cases entirely confirmed the conclusion that the Broad Street pump water was mainly instrumental in propagating the outbreak of disease.

In further confirmation of the view that water is a fertile agent in spreading the disease, the instance may be adduced of the outbreak of cholera on board a steam-vessel in 1866 recorded by Parkes ('9th Rep. of the Med. Officers of the Privy Council for 1866,' p. 244); the case of Utrecht ('Med. Times and Gaz.' 1869, I. p. 626); and the striking coincidences in Scotland between the abatement of cholera and the introduction of a fresh and pure water-supply. ('Trans. of the Royal Scottish Soc. of Art,' vol. vii. 1867, p. 341, quoted by Parkes).

It must be admitted that this statistical evidence is inconclusive, and that it has been severely criticised by eminent authorities. It is, however, in accord with other data, and cannot be ignored. When supplemented by the data derived from the investigation of individual circumstances of outbreaks of cholera, its significance becomes manifest.

In Germany the connection between cholera and contaminated water-supply has not obtained general acceptance; and the great authority of Pettenkofer could find no evidence from the experience of Munich in favour of the theory ('Zeitschr. f. Biol.' Bd. I, p. 353). Günther, too, asserted that in 1865 no connection could be traced in Saxony between impure drinking-water and cholera ('Cholera in Sachsen im Jahre 1865,' p. 125, quoted by Parkes). But the subsequent experiences of Richter ('Arch. d. Heilk.' 1867, p. 472), and Dinger (*ibid.* 1867, p. 84), and others, have tended to establish such a connection. In India many observers have denied the causal connection of water and cholera; and the late Dr. J. M. Cunningham, once a firm believer in the connection, subsequently renounced the theory of the water-carriage of cholera. It cannot, therefore, be asserted that the theory is fully established to the satisfaction of all competent observers. It may be that the conditions of the dissemination of cholera may be different in India from those which obtain in the cooler climate of England; but this is hardly supposable to be the case when England and Germany are compared.

Typhoid Fever

This endemic fever kills some five or six thousand people annually in England and Wales out of a population of twenty-six millions, or 0·2 per 1000. The poison of typhoid indubitably exists in the bowel evacuations of those suffering from the disease, and hence is very frequently introduced into drinking-water, which, as is now well known, thus becomes a chief, but by no means the sole, agent in the distribution of typhoid. Moreover, it is now pretty generally accepted that the germ of typhoid is a bacillus (*Bacillus typhosus*, E. Corth), or rod-shaped schizomycete. It is stated that inoculation experiments made with this bacillus have been successful (Renkel u. Simonds' 'Die Ætiol. bed. des *Typhus bacillus*'). But long before this discovery was announced the connection between typhoid and water-supply had been one of the best established conclusions of scientific medicine; and the discovery of the active bacillus of typhoid seemed from a public-health point of view merely to support the definite conclusions arrived at by statistical and individual inquiries into the causation of the disease.

The proofs of this assertion lie elsewhere. In 1854 typhoid fever, then the scourge of Millbank Prison, which drew its water from the polluted Thames, was practically extinguished by the cessation of the old supply and the adoption of a water-supply from the deep artesian well in Trafalgar Square ('Lancet,' 1872, I. p. 787).

In 1867 a severe outbreak of typhoid fever at Terling, in Essex, was investigated by Dr. Thorne by order of the Privy Council. One-third of the inhabitants of Terling were attacked by the disease, and the death-rate was 45 per 1000 of the population. Three weeks after the appearance of the first (and perhaps imported) case, the disease broke out with alarming virulence, and no class of persons was exempt. The epidemic was preceded by a drought, and was coincident with a rise of water in the village wells consequent on heavy rainfall; and these wells were much exposed to pollution by excremental filth. Indeed, in summer, to use the expression of a resident, they were 'nothing better than stinking pools.' There was, moreover, ample proof of the connection between the rise of water in the wells and the attack of the disease.

This Terling outbreak was a signal instance of the immunity from typhoid often seen in a population habitually drinking a filthy water, so long as this contains no specific contaminating material. The introduction of the

specifically polluted filth from typhoid stools at once determined, however, a virulent epidemic of typhoid fever ('10th Report of the Med. Off. of Privy Council,' 1867, p. 41).

Other instances may be adduced in confirmation of the teachings of the Terling outbreak.

The most striking instance illustrative of the occasional persistency of the typhoid, and other similar poisons, when they are diffused in water, and then exposed to oxidising influences, occurred at the village of Lausen, near Bâle, in Switzerland, and was investigated by Dr. A. Hägler, of Bâle ('Deut. Vierteljahrsschrift f. öffentl. Gesundheitspflege,' Bd. VI. S. 154; and '6th Report of the Rivers Pollution Commissioners,' p. 463). In this previously healthy village, which had never been known to be visited by an epidemic of typhoid fever, and in which not even a single sporadic case of the disease had been observed for many years, an epidemic broke out in August 1872, which attacked almost simultaneously a large proportion of the inhabitants. Some miles south of Lausen, and separated from it by the mountain ridge of the Stockhalden, lies the small parallel valley of the Fürlerthal. In this valley lived a farmer, in a solitary farmhouse, who was attacked on June 10 by typhoid fever, just after his return from a long journey. A girl was attacked in the same house on July 10; and in August the farmer's wife and son sickened of the same disease. There was no communication, so far as could be ascertained, between the farmhouse and the village of Lausen. On August 7, ten of the villagers in Lausen were attacked by typhoid, and within the next nine days the number of cases had risen to 57, out of a population of 780 living in 90 houses. Within the first four weeks of the epidemic the number of cases rose to 100, and at the close of the epidemic, at the end of the following October, 130 persons—or 17 per cent. of the inhabitants—were attacked; besides 14 children infected in the village during their holidays, and who sickened with typhoid after their return to schools in other places.

Except in six houses, which were supplied with water from their own wells, the cases were pretty evenly distributed throughout the entire village, and the above six houses were exempt from typhoid. This remarkable fact threw suspicion upon the public water-supply, which came from a spring at the foot of the Stockhalden ridge, which is probably an old moraine of the glacial epoch, and such a source might reasonably be regarded as above suspicion of pollution. Observations upon a brook in the Fürlerthal Valley and of the spring at Lausen showed, however, that there was a direct communication between the two. Among the observations it was noted that whenever the meadows—below a hole spontaneously formed ten years before by the giving way of the soil a little below the farmhouse—were irrigated with water from the Fürler brook, the volume of the Lausen spring became greatly increased within a few hours. This irrigation had been carried on during the summer, from the middle to the end of July, the brook being polluted by the typhoid dejecta of the farmhouse patients. It was in direct communication with the closets and dungheaps of the infected house; all the chamber slops were emptied into it, and the dirty linen of the patients was washed therein. It was observed, also, that the water supplied to Lausen was at first turbid, acquired an unpleasant taste, and increased in volume. Three weeks or so after the commencement of the irrigation the epidemic began in Lausen. But Dr. Hägler did not rest satisfied with this evidence, and made the following experimental demonstration of the correctness of the assumption that the epidemic was due to the pollution of the Lausen water-supply by the dejecta of the typhoid patients in Fürlerthal. The above-mentioned hole in the Fürler valley was opened, and the brook led into it; three hours later the

fountains of Lausen gave out double their previous delivery of water. A solution of 18 cwt. of common salt in water was now poured into the hole, and soon the Lausen water was found to react more strongly for chlorides than before; the chlorine reaction went on increasing, and the proportion of saline matter in the fountains had increased threefold. All doubt as to the passage of water from the fever-stricken Fürlerthal to Lausen being thus removed, the question as to whether the water found its way through natural fissures, or percolated through porous strata, was attempted to be solved by carefully and uniformly diffusing 2½ tons of flour through water, which was then thrown into the hole. But neither an increase in the amount of solid constituents nor any turbidity of the Lausen water was observed to result from the addition. It appears to the writer, however, that this experiment, in the face of the previously observed turbidity of the fountains whilst irrigation was going on in the Fürler valley, is not conclusive against the possibility of the water finding its way from Fürlerthal to Lausen by natural conduits. Two things this interesting epidemic does, nevertheless, prove beyond doubt: first, that animal excreta do not, when taken in drinking-water, produce typhoid; and next, that typhoid excreta may, when introduced into a water-supply, induce typhoid in a distant community, when the water in its passage is not freely exposed to the atmosphere.

It is perhaps unnecessary to introduce further instances in illustration of the two important facts that typhoid fever may be spread by the use of contaminated drinking-water, and that in places where typhoid fever has been habitually prevalent, the disease may be practically eliminated by the introduction of a pure water-supply.

Diarrhœa

That diarrhœa may result from the drinking of impure water, no sanitarian will doubt. The diarrhœa thus produced may be of a varied character, and be due to a variety of causes.

1. *Sulphuretted hydrogen* in a water may cause diarrhœa. In the Mexican war of 1861–2, such a form of diarrhœa was produced by the drinking of water abounding in alkaline sulphides (Poncet). Medicinal sulphuretted waters (e.g. those of Harrogate) are well-known purgatives. Other fœtid gases in water (e.g. sewer gases) may produce a similar result.

2. *Suspended matters*, animal (fæcal), vegetable, and mineral, may cause diarrhœa. Some of these—e.g. clay, mica, &c.—may act as simple mechanical irritants, whilst suspended animal and vegetable substances may act specifically upon the intestinal tract.

3. *Dissolved Nitrogenous Organic Matter.*—An excess of this, if of animal origin, may provoke diarrhœa. That derived from cemeteries is generally supposed to do this in a marked manner. The writer's experience is, however, that such dissolved matters are not generally more prone to do this than other animal substances.

Dissolved vegetable matters appear to have no marked effect, except in the case of peaty and marshy waters. Mr. Wanklyn, nevertheless, has drawn attention to the circumstances of Leek Workhouse, where, for several years, there was a general tendency to diarrhœa, which was not accounted for until the water was examined and shown to be loaded with vegetable matter; and he also instances the case wherein a well on Biddulph Moor, in the same district of Staffordshire, yielded on analysis only 0·5 grain of chlorine per gallon—showing absence of any appreciable sewage contamination—but yielded a rather considerable quantity of albuminoid ammonia

(0·14 part per million, or 0·0098 grain per gallon). Persons who were in the habit of drinking this water suffered from diarrhœa ('Water Analysis,' p. 49).

4. *Dissolved Mineral Matters.*—These, even when of the most simple and innocuous character, when in excess may have a purgative effect, as is seen in the case of many purgative medicinal waters. Sulphate of magnesium and sulphate of calcium are most notable as producing this effect. The illness produced may be of a specific character, as in the case of contamination by lead (q.v., p. 256) or by chromium.

Dysentery

Impure water is credited with being a fertile source of dysentery. The connection of this disease with the use of impure water has been recognised for nearly a century. Cornuel records an outbreak of the disease at Guadaloupe in 1847, caused by the use of impure water; and the Walcheren fever, in 1809, was associated by Davis (' On the Walcheren Fever'), with the drinking of impure brackish water. Chevers in India, Champouillon in France, and McGrigor in the Spanish Peninsula, have each observed outbreaks of dysentery from the same now well-recognised cause. Generally, it may be stated that those forms of water-pollution—gaseous, soluble, and suspended matters—which produce diarrhœa may, under other circumstances, produce dysentery.

Affections of Mucous Membranes

The effects of impurities in drinking-water are not limited to the intestinal tract, and may affect other portions of the alimentary and other mucous membranes. Gastro-intestinal catarrh is, perhaps, not an infrequent result of the use of impure water.

Influence of Earthy and Metallic Impurities

These have already been sufficiently treated of under various headings (see Lead, p. 256, Chromium, p. 256, and Magnesium Salts, *supra*).

Yellow Fever

It is most uncertain whether this disease is propagated by means of water, the evidence as to this being conflicting.

Malaria from Water

Simple peaty water is not generally decidedly unwholesome, though it not seldom produces temporary diarrhœa when drunk by those unaccustomed to its use. Marsh-water has, however, from early times been considered unwholesome and a provocative of disease. Hippocrates refers to the popular notion in his time, that those who drink the water of marshes get hard and enlarged spleens. The inhabitants of marshy tracts of country are pretty generally agreed that these waters may produce fevers. Dr. E. Parkes states that on inquiring in the malarious plains of Troy during the year 1854, he was informed by the villagers that those who drank marsh-waters had ague at all seasons, whilst those who drank pure water only got ague during the late summer and autumn; and he adds from his Eastern experience that the same belief prevails in South India. Mr. Bettington, of the Madras Civil Service, stated that it was notorious that marsh-water

produces fever and affections of the spleen; and he instanced a notoriously unhealthy village in which by simply digging a well the inhabitants were freed from these maladies.

Indeed, medical literature, and especially the annals of the Indian and British military services, abound in striking instances apparently pointing the connection between marsh-water and aguish attacks as cause and effect.

Nevertheless there are anomalies and apparent exceptions to this connection, well deserving of more rigorous investigation than they have hitherto received. Thus it is asserted that the water of the celebrated Dismal Swamp of the North American Continent—a typically marshy water—is not injurious to health, but is held in high estimation for use on board ships. This instance is, however, inconclusive, since it is a notorious fact that water charged with organic impurities, more especially of vegetable origin, when stored undergoes a kind of fermentation which materially alters its character, and may as the result render a highly impure water palatable and wholesome.

The evidence as to the unwholesomeness of marsh water is to the writer's mind conclusive.

Goitre

That impure drinking-water is the cause of goitre has been a prevailing opinion among physicians since early times; and it is even stated that by drinking certain waters French and Italian soldiers can produce that disease, and so claim exemption from conscription. The evidence in favour of goitre being caused by the use of certain kinds of drinking-water is undoubtedly very strong, and probably well founded; but the nature of the substance which produces goitre is unknown. The absence of iodine, and the presence of an excess of magnesium salts, also excessive hardness, have all been credited as exciting causes; and yet each one of these alleged causatives has been found absent in the waters drunk by those living in goitrous districts. Thus iodine has been found present, and Dr. J. B. Wilson found that at Bhagsoo, Dharmsala, India, where goitre prevails, all the waters of the district are soft, non-calcareous, and destitute of magnesian compounds (Aitkin's 'Science and Practice of Medicine'). Usually, however, goitre prevails mostly in calcareous soils, and especially where the water-supply is drawn from the magnesian limestone formation. Nevertheless, goitre does not appear to be a prevalent disease in Sunderland or in Bristol, towns which have water-supplies which are hard, calcareous, and exceptionally rich in magnesium salts.

Evidently, the whole subject of the relation of goitre to water-supply needs reinvestigation. A large mass of information on the subject is given by Saint-Lager ('Sur les Causes du Crétinisme et du Goître endémique').

Parasitic Diseases

Impure water, containing the ova of entozoa, &c., is a fertile source of parasitic disease in warm climates, and perhaps to a much less extent in the temperate climate of Great Britain, where, it must be admitted, water-supplies are much less prone to contain the ova of entozoa, in consequence of the less filthy habits of our people than in Poland, Russia, and other temperate climates.

The following is a list of the infecting organisms which have been alleged to have been found in drinking-water:

1. *Tænia lata* (*Bothriocephalus latus*).
2. *Distoma hepaticum* (fluke).
3. *Ascaris lumbricoides* (round worm).
4. *Filiaria Dracunculus* (Guinea-worm).
5. *Filiaria sanguinis hominis.*
6. *Oxyuris vermicularis.*
7. *Dochmius duodenalis* (*Strongylus duodenalis ; Sclerostoma duodenale ; Anchylostomum duodenale*).
8. *Billharzia hæmatobia.*
9. *Sanguisuga medicinalis* (the speckled leech), *S. officinalis* (the green leech), and other species of leech.

WATER ANALYSIS

The Collection of Samples of Water

The proper collection of samples of water for analysis is all-important as regards the method of taking the samples, the cleanliness of the vessels employed, and the quantities requisite. The quantity of water required for an analysis will vary according to the kind of analysis which it is desired to make. A full analysis of all the constituents is rarely required. Usually half a gallon suffices for the purposes of an ordinary analysis for sanitary purposes.

A glass-stoppered bottle of the kind known as the 'Winchester Quart' is the best bottle to be used for the purposes of collecting and storing the sample. These bottles hold rather more than half a gallon. A clean new well-rinsed cork may be substituted for a stopper, if one be not at hand. The bottle should be well cleansed, and rinsed with clean tap-water. It is always undesirable to use an opaque vessel, such as a stoneware jug, for the collection of samples of water, as their cleanliness and freedom from contaminating material can never be ensured.

Before filling the clean bottle with the sample, it should be rinsed three or four times with the water to be collected before filling it with the actual sample. Care should be taken to ensure the fairness of this, by pumping to such an extent as to previously empty the barrel of a pump; by careful dipping in a stream; and by avoiding disturbing the sand or mud at the bottom of a well, spring, or rivulet. In rivers the sample should be taken from mid-stream, avoiding the outlets of sewers and the inlets of tributary streams. The vessel in which the sample is collected should be filled to within half an inch of the cork or stopper, which should then be tied down with tape or string, a seal being placed upon the knot, and another upon the top of the stopper or cork so as to fix the string. No sealing-wax or luting should be placed around the aperture of the bottle.

A 'tie-on' luggage label, with description of the sample and the date, should be affixed to the neck of the vessel, and secured by a seal. The use of adhesive labels is attended with risk; they are easily detached when wetted, and an ignorant person may replace a label on a wrong bottle. Moreover, the purposive transposition of labels by interested persons has been known to occur.

For special purposes, and where a mineral analysis is required, a larger quantity of water may be necessary—a gallon or more.

In collecting samples of water for bacteriological examination, flasks of three or four ounces' capacity may be employed. These are cleansed, plugged

with cotton-wool, and then sterilised. The plug is removed by means of the fingers or sterilised forceps when the sample is collected, taking care not to touch the interior of the neck of the flask with the fingers. About an ounce of the water is introduced by means of a sterilised pipette, and the plug replaced; the top of the flask may then be secured by means of a caoutchouc cap which has been kept in a 1 in 1000 solution of corrosive sublimate. The flasks are transported with difficulty, since the sample should at no time be allowed to touch the plug. A glass bulb with a slender neck forms a better receptacle when the sample has to be transported to a distance; the bulb being hermetically sealed, as recommended by Magnin and Sterberg ('Bacteria,' p. 175).

In the case of spring and well waters, the nature of the soil, subsoil, and geological characters of the locality should be carefully noted.

The analysis should be made at the earliest possible opportunity. If delayed, ammonia may decrease, or nitrates may in part disappear, odour may be lost, and deposit may take place owing to escape of carbonic acid gas or absorption of oxygen, or from both causes.

Gases

A determination of the nature of these is not frequently necessary, and a quantitative determination of each of them is seldom of much service for the purposes of sanitation. If required, special precautions are necessary, and some of the operations must be conducted at the spring or well, as the case may be. The presence of any special odorous gas such as sulphuretted hydrogen may be noted.

Preliminary Examination

Colour and Appearance.—This is best observed in a clear glass tube, two feet long and two inches in diameter, closed at one end by a plate of thin colourless glass, cemented on to the tube with an uncoloured cement. By placing the tube on a piece of white printed paper, such as the page of a book, the colour of the water, its transparency or turbidity, and other points connected with its appearance, may be readily noticed. By only half-filling the tube, so that the lower half contains water and the upper half air, and placing the tube in a good light, and backed by a piece of white paper, further information as to the tint of the water will be obtained.

Odour.—Some waters exhale special odours even in the cold, such, e.g. as sulphuretted waters. When no odour can be thus perceived, put 100 c.c. of the sample into a clean wide-mouthed stoppered bottle holding 200 c.c., and raise the temperature to about 100° Fahr. (38° C.). Shake vigorously, remove the stopper, and immediately apply the nose to the botttle. Some polluted waters when thus treated give off distinct and easily recognisable odours.

Turbidity.—If a water be turbid, the nature of the turbidity should be ascertained; and if considerable, its quantity should be determined. For the former purpose about 200 c.c. of the water may be placed in a tall conical glass, and the deposit allowed to subside, the vessel being kept carefully covered so as to avoid access of dust. A small quantity of the deposit may then be removed by a pipette and subjected to microscopical examination. The supernatant water may then be siphoned off and the residue treated with hydrochloric acid so as to ascertain whether it is chalky matter or insoluble clay, sand, or earth.

In order to determine the amount of suspended matter, a definite volume of the water—say a litre—is filtered through a tared Swedish paper filter

the residue dried at 130° C. (100° C. Frankland) and weighed. On deducting the tare of the filter, and multiplying by the necessary factor to reduce the quantity to 'grains per gallon,' or 'parts per 100,000' if desired, the 'total suspended matter' is obtained.

By incinerating the filter with the deposit, moistening with solution of carbonate of ammonium, and drying at a heat below dull redness (or at 180° C), deducting the weight of a similar filter-ash, the 'mineral suspended matter' is obtained. The difference between the total and the mineral suspended matter is the 'organic suspended matter.'

Microscopical Examination of Deposits

This important operation should never be omitted in the analysis of a water, as by its means very valuable information will frequently be obtained, both of a positive and of a negative character: positive when organisms of definite character are found pointing to organic pollution; and negative when a turbidity or deposit objectionable to the eye is ascertained to be due to inert mineral matter removable by a simple process of filtration.

When a water is highly turbid, a sufficient quantity of deposit may readily be obtained for microscopical examination, but it is otherwise when the amount of turbidity is slight; and this is most commonly the case with an ordinary drinking-water. In such cases the method recommended by Dr. Macdonald may be employed. ('Microscop. Exam. of Drinking Water,' p. 1.) A tall glass vessel holding half a litre or a litre is filled with the sample, and a circular disc of glass resting upon a horizontal loop at the end of a long wire is let down to the bottom of the glass, and the whole apparatus is covered and set aside for twenty-four hours, or longer if necessary. At the end of this time the water is syphoned off, only leaving a thin stratum over the glass disc, which is gently raised, and laid on a sheet of blotting-paper so as to dry its under-surface, when it may at once be transferred to the stage of the microscope after covering the deposit with a large thin covering-glass. Instead of a disc of glass, an ordinary microscope slide may be employed; but its form is not convenient for immersion. Generally, however, it suffices to allow the sample to deposit in a large stoppered collecting-bottle, such as a Winchester quart. The water is then in greater part syphoned off into another bottle, and the remainder with the deposit is poured into a conical glass, which is covered and set aside. The deposit can then be easily removed by a pipette in sufficient quantity to be transferred to a slide, and submitted to microscopical examination. A $\frac{1}{4}$th or $\frac{1}{6}$th inch objective will usually suffice for the examination, and many organisms are better seen when a lower power is used. It must be remembered that this examination does not supersede a bacteriological examination (see p. 296).

The objects thus seen are very varied: angular, crystalline, and rounded mineral particles; the pollen of flowers; epidermic and deeper tissues of plants; fibres of linen, cotton, silk, and wood; vegetable living or dead organisms, from the minute bacterium to strings and filaments of confervoid plants; diatoms; animal fibres and organisms of varied type and conformation; ova of animals, &c. For a full description of these we must refer to other works, and especially to the one already referred to: 'A Guide to the Microscopical Examination of Drinking Water,' by Dr. J. D. Macdonald. 2nd ed. 1883.

Under certain conditions the microscopical examination of water may afford valuable negative, if not positive, results. Thus, for example, it may be important to ascertain whether a water contains cholera-evacuations. In

this case plate cultivations may be made, and if the characteristic Asiatic cholera spirillum be obtained and distinguished from other comma-shaped bacilli, its presence will indicate that the water contains cholera-evacuations, whatever be the view held as to the causation or non-causation of cholera by that spirillum, which is at all events pretty generally accepted as being an accompaniment of true cholera.

The microzyme test as hitherto usually employed is valueless, viz. the test of adding a few drops of the sample of water to a small quantity of Pasteur's nourishing fluid previously boiled in a sterilised tube. The subsequent milkiness developed in the liquid only proves that the water contains micro-organisms or their spores, and these are present even in ice and in ordinary potable waters: hence no results of real value are obtainable in this way.

Taste

The taste and palatability of a water is important to be noted. It is not advisable, however, to taste a water when there is reason to apprehend that it is specifically polluted.

The taste of a water depends much upon the quantity and quality of its saline constituents; and still more on the gaseous constituents. Imperfectly oxidised organic impurities, such as sewage, may confer special odours on a water.

Acidity, Neutrality, or Alkalinity

Most waters react faintly alkaline to delicate neutral tint litmus-papers. Rain-waters and peaty waters are generally slightly acid in reaction.

If it be desired to determine the extent of acidity of a water, this may be done by placing half a litre in a flask provided with a reflux condenser, and boiling the water vigorously for fifteen minutes or so, to expel carbon dioxide. The acidity is then determined by running in decinormal soda solution from a burette, using phenol-phthalein as an indicator. Some analysts prefer to use methyl-orange to determine the point of neutrality. By operating on two separate half-litres, using the two indicators respectively, a distinction may be made between mineral and organic acids.

Total Solids or Saline Constituents

A platinum basin capable of holding 350 cubic centimetres is cleaned, rinsed with distilled water, dried in an air-oven at 130° C., cooled in an exsiccator over sulphuric acid, quickly weighed, and the tare of the dish noted. 250 c.c. of the water under examination are pipetted into the basin, and evaporated to dryness. This is best done entirely on the water-bath, but may be partially effected over a naked flame. In all cases the completion of the evaporation must be effected on the water-bath. The dish with its contents when dry is transferred to an air-oven heated to 130°, 150°, or 180° C., till it practically ceases to lose weight, or for a definite period, say half an hour. Various analysts have recommended each of the above-named temperatures; but the temperature of 130° C. is the one most commonly adopted. At this temperature hydrated sulphate of calcium readily gives up three-fourths of its water, and undergoes no further loss below 200° C.—an inadmissible temperature for drying a water residue. This last temperature is, moreover, requisite for the complete dehydration of chloride of calcium. But whatever be the temperature employed, it is well to note it in the analytical report, so that the results may be compared with those of other analysts. The dish

and contents are again cooled in the exsiccator, and rapidly weighed. The difference between the new weight thus obtained and the original weight of the dish is, of course, the weight of the solids in 250 c.c., of the water, which, multiplied by 280 and by 400 respectively, gives the solids in grains per gallon and in parts per 100,000 respectively.

Dr. Frankland recommends the evaporation of 500 c.c. of the sample, with special precautions, and the drying of the evaporated residue in the water-oven at approximately 100° C. for three hours, in order to obtain the total solids ('Water Analysis,' p. 17). Mr. Wanklyn, on the other hand, uses 70 c.c. only, and dries for ten minutes only in the water-oven. His published analyses by this method, which he says are 'very concordant,' show weighings made apparently to the extraordinary minuteness of 0·01 milligramme. 70 c.c. is too small a quantity to use when anything nearer than a rough approximation to total solids is desired.

Loss on Ignition (also sometimes termed 'organic matter and water of hydration').—This determination is obtained with the greatest accuracy by placing the platinum basin with its solid contents resting on a clay triangle inside a larger dish, over which is suspended at a short distance a plate of platinum, and gently heating the outer dish by means of an argand burner. The outer dish may ordinarily be dispensed with, care being taken to avoid a heat exceeding that of dull redness, otherwise alkaline chlorides may be volatilised. The heat must be continued till all sooty particles are dissipated. The evolution of ruddy fumes, indicating the presence of nitrates or nitrites, is noted, and also the production of special odours, such as those of burning nitrogenous organic matter. In this way valuable information may be obtained. With care, no loss occurs from the decomposition of carbonates; but it is always advisable to moisten the incinerated residue with a solution of carbonate of ammonium, dry, and again very gently incinerate, so as to insure the full carbonation of the residue; and when the water abounds in nitrates this treatment with carbonate of ammonium is indispensable. When cold, the weight of the dish and its contents deducted from the similar weight of the dish *plus* the total solids gives the loss on incineration, which is then calculated into parts per 100,000, or grains per gallon if desired, by multiplying by 400 or by 280 respectively. It is customary to disparage the value of this determination, but it is one which an experienced analyst will never omit; and by observing the manner in which the incineration progresses, the gases and vapours given off, &c., much valuable information may be gained as to the kind of organic matter present in the water.

When the water contains considerable quantities of nitrates, a correction is necessary owing to the substitution of the radical CO_2 for the radical N_2O_5 in the nitrates; $CaO.\ N_2O_5$, for example, having the molecular weight 164, becomes $CaO.\ CO_2$, having the molecular weight 100. The rule is to deduct from the experimental loss on ignition 2·29 for each unit of 'nitrogen as nitrates and nitrites' present, or 0·59 for each unit of nitric acid, N_2O_5. In the case of many magnesian waters, the loss on ignition is increased by the loss of hydrochloric acid during evaporation, aqueous chloride of magnesium being converted on evaporation into magnesia, with loss of hydrochloric acid.

Chlorine

This is best titrated by means of a standard solution of nitrate of silver, each 1 c.c. of which will precipitate 0·001 gramme of combined chlorine. The solution is prepared by dissolving 4·79 grammes of recrystallised nitrate of silver in distilled water, and making up with additional water to the

volume of a litre. Its exact strength is determined from time to time by setting it against a standard solution of chloride of sodium, containing 1·648 gramme of ignited (not fused) clean rock-salt crystals, in a litre of distilled water. Or pure chloride of sodium may be prepared by precipitating a saturated solution of common salt by passing a current of hydrochloric acid gas into it, and then collecting, rinsing with distilled water, and drying at 300° C. the crystals which have been thrown down from the solution.

In performing the analysis, 50 c.c. of the water is pipetted into a white porcelain dish, and one or two drops of a half-saturated solution of neutral yellow chromate of potassium added. The chromate solution when acidulated with nitric acid must remain perfectly clear when a drop of the solution of nitrate of silver is added to it, proving the absence of chlorides. If now the standard solution of nitrate of silver be run from a burette into the water to be analysed, and to which the chromate has been added, a red precipitate of chromate of silver will be formed around the inflowing solution, but will quickly disappear on stirring the liquid in the dish, the red chromate of silver being decomposed, and white chloride of silver formed, so long as any chloride remains in solution. But when the chlorine is all converted into chloride of silver, the slightest excess of the standard solution instantly strikes a red colour, due to the permanent precipitation of chromate of silver. Hence the chromate acts as an indicator, and when the slightest tinge of red colour is visible on stirring the liquid, the reaction is terminated, and the quantity of standard solution that has been added is read off. The number of cubic centimetres added multiplied by 1·4 gives the grains of chlorine per gallon, and by 2 the parts of chlorine per 100,000. The quantity of chlorine multiplied by 1·648 gives the amount of chloride of sodium which is equivalent to the combined chlorine present.

It is well to discharge the colour of the liquid in the dish on the completion of the titrations by adding a few drops of a solution of chloride of sodium, and repeating the titration in another dish on a fresh quantity of the water. When the two dishes are viewed side by side, any shade of difference in the colour of the solutions will be easily perceptible.

Some analysts prefer to use a decinormal silver solution (17 grammes of nitrate of silver per litre) and operate on a large volume, say 250 c.c., of the water. Each 1 c.c. of this solution precipitates ·00355 gramme of chlorine; hence if 250 c.c. of water be used for titration, the number of cubic centimetres of silver solution multiplied by 0·994 gives the grains of chlorine per gallon, or by 1·42 the parts of chlorine per 100,000 of water.

Dr. Frankland uses a solution of half the strength here recommended, using 50 c.c. of the water for titration. Each 1 c.c. of his nitrate of silver solution = 0·0005 gramme chlorine (' Water Analysis,' p. 20).

Nitrates

1. *Indigo Process.*—A standard solution of indigo is prepared by dissolving commercial indigo-carmine in water containing 5 per cent. by volume of sulphuric acid, and boiling for some time so as to sterilise the solution. It is then standardised against a very dilute solution of nitrate of potassium, which may be conveniently made of such a strength that 1 c.c. = ·0001 gramme N_2O_5, or a solution containing 0·187 gramme nitrate of potassium in a litre of water. In diluting the indigo solution to the proper strength, distilled water containing 5 per cent. by volume of sulphuric acid should be used. When thus prepared the solution keeps well. The process is conducted as follows:

20 c.c. of the water (or to standardise the indigo, 10 c.c. of nitrate of potassium solution and 10 c.c. distilled water) are measured into a beaker of about 100 c.c. capacity, standing in a small flat porcelain dish; 1 c.c. of standard indigo solution is run in from a burette, and then 21 c.c. of strong sulphuric acid (free from oxides of nitrogen and of sp. gr. 1·84) are cautiously poured in, so as not to mix with the liquid in the beaker. As soon as the blue colour of the indigo begins to fade, the mixture is stirred, when the temperature rises to 120°–130° C. The indigo solution is then rapidly run in from the burette till a permanent blue colour remains. The volume of indigo solution required is noted: say 10 c.c. A fresh 20 c.c. of water is taken, 10 c.c. of indigo solution added, and a volume of sulphuric acid equal to the whole (30 c.c.) cautiously added, and the mixture stirred as soon as decoloration commences.

The process is repeated until, in the final experiment, the volume of indigo solution added to the 20 c.c. water in the beaker, on mixing with a volume of sulphuric acid equal to the bulk of water *plus* indigo solution, leaves a faint blue tint after stirring. In each experiment the bulk of acid used must equal the volume of liquid to which it is added, in order to attain the proper temperature on mixing. The number of c.c. of indigo solution used multiplied by 0·5 gives parts per 100,000, or by 0·35, grains per gallon of N_2O_5.

In cold weather it is advisable to slightly warm the mixture of indigo solution and water before adding the acid.

Should a water require more than about 10 c.c. indigo solution for 20 c.c. water, the sample should be appropriately diluted. For very small quantities of nitrates a dilute solution of indigo may be used—$\frac{1}{5}$th or $\frac{1}{10}$th the strength of the above solution—the operation being conducted in the manner already described.

2. *Phenol-Sulphuric Acid Method.*—This method is simple in its application, and yields good results. Phenol-sulphuric acid is prepared by melting absolute phenol, and pouring two parts, by measure, of the liquefied phenol into five volumes of pure concentrated sulphuric acid free from nitrates, when the whole is digested for eight hours in a water-bath kept boiling. The mixture is then allowed to cool, and to each two volumes of the liquid is added one and a half volumes of distilled water, and half volume of pure strong hydrochloric acid solution. The light brown solution thus obtained is ready for use. The following is a good mode of procedure (' Chem. News,' 1890, vol. 61, p. 15).

10 c.c. of the water under examination and 10 c.c. of a standard solution of nitrate potassium (0·7215 gramme per litre) are pipetted into two small beakers, and placed near the edge of a hot plate. When nearly evaporated, they are removed to the top of the water-oven and left there till they are evaporated to complete dryness. As this operation usually takes about an hour and a half, it is better, when time is an object, to evaporate to dryness in a platinum dish over steam. The residue in each case is then treated with 1 c.c. of the phenol-sulphuric acid, and the beakers are placed on the top of the water-oven. If the water under examination contains a large quantity of nitrates, the liquid speedily assumes a red colour, which in a good water will not appear for about ten minutes. After standing for fifteen minutes the beakers are removed, the contents of each washed out successively into a 100-c.c. measuring-glass, a slight excess (about 20 c.c.) of ammonia solution (sp. gr. 0·96) added, the 100 c.c. made up by the addition of water, and the yellow liquid transferred to a Nessler glass (6 in. × $1\frac{1}{2}$ in.). The more strongly coloured liquid is then partly transferred to the measuring-

glass again, and the tints compared a second time. In this way the tints are adjusted, and, when as far as possible matched, the liquid that has been partially removed is made up to the 100 c.c. mark with water, and, after well mixing, finally compared. If not of exactly the same tint, a new liquid can at once be made up, probably of exactly the same tint, as the first experiment gives very nearly the number of c.c. of the one equivalent to the 100 c.c. of the other. Each 1 c.c. of the nitrate solution used = 0·0001 gramme N.

In the case of very good waters, 20, 50, or more c.c. should be evaporated to a small bulk, rinsed into a small beaker, and evaporated to dryness, and treated as above—only 5 c.c. of the standard nitrate of potassium (= 0·5 N in 100,000) being taken. In the case of very bad waters, 10 c.c. should be pipetted into a 100 c.c. measuring-flask, and made up to the mark with distilled water, then 10 c.c. of the well-mixed liquid (= 1 c.c. original water) withdrawn, and treated as above.

3. *Aluminium Process.*—This is the process recommended by Mr. Wanklyn. It is thus performed: Caustic soda is prepared free from nitrates by dissolving metallic sodium in water, 2 grammes of the metal being used for each 100 c.c. distilled water, which is then boiled to expel ammonia. A definite volume, say 50 c.c. or 100 c.c., of the water to be examined is mixed with its own volume of this soda solution, and a piece of aluminium-foil, more than the liquid will dissolve, is placed in the mixture and allowed to remain for several hours. The liquid is then distilled, and in the distillate the ammonia formed by reduction of the nitrates is titrated by means of Nessler's solution. Each unit of ammonia found corresponds to 0·8235 unit of 'nitrogen as nitrates,' or to 3·176 units of N_2O_5. If 100 c.c. of water were employed, by multiplying the results obtained by 700 the number of grains per gallon is obtained; or by moving the decimal three places to the right, we get parts per 100,000.

In using the process Dr. Frankland advises the use of a 10 per cent. solution of soda, made free from nitrates by dissolving 4 inches square of aluminium-foil in it, and boiling off one-third of the liquid. In the actual performance of the analysis 100 c.c. of the water are treated with 10 c.c. of the above soda solution, evaporated to one-fourth, and then treated with 2 inches square of aluminium-foil for six hours before distilling off the ammonia ('Water Analysis,' p. 30).

4. *The Zinc-Copper Couple Method.*—This method, devised by Dr. Gladstone and Mr. Tribe, depends upon the electrolytic reduction of nitrates to ammonia by means of a couple of the two metals copper and zinc, which is prepared as follows: A mixture of 2 grains of finely divided reduced copper with 18 grains of coarse zinc filings is introduced into a 2 oz. flask fitted with a cork, through which passes a tube drawn out to a capillary opening. The flask is heated over a burner till the zinc begins to soften, shaking gently all the time to ensure thorough mixture of the two metals, and to prevent any part being overheated. The mass, when the operation is finished, should consist of greyish-black grains, without metallic lustre. If the mass has a brassy tint, or if the zinc filings retain their form, the product must be rejected. As soon as the desired result is obtained, the flask is removed from the flame, continuing the agitation for a few seconds to prevent fusion. The point of the capillary tube is then sealed, and the flask allowed to cool.

In performing the analysis 250 c.c. of the water may be evaporated over a naked flame to about the volume of 25 c.c., a fragment of quicklime about the size of a hemp seed added, and the evaporation renewed till the bulk is

reduced to 6 or 7 c.c. The whole is then rinsed into an 8 oz. distilling-flask, and the requisite amount of zinc-copper couple added. The flask is closed with a cork, and attached to a small Liebig's condenser, and the water nearly all distilled off. Hot distilled water is added at intervals, and the distillation renewed till 100 c.c. of distillate is obtained. This after appropriate dilution of a fraction, say 5 c.c., made up to 50 c.c., is then nesslerised.

5. *Frankland's Process.*—Dr. Frankland estimates the total amount of nitrogen present in the form of nitrates and nitrites by a method—that of Crum—based upon the reduction of the acids of these salts by means of mercury. A litre, or even half a litre, of the water is evaporated to a small bulk, sulphate of silver is added to precipitate chlorides, and the mixture is filtered. When the water contains nitrites, these are converted into nitrates before the evaporation by means of permanganate of potassium. The filtered liquid is evaporated to a bulk of 2 or 3 c.c., and transferred to a glass tube open at one end, and furnished with a stopcock and funnel-shaped mouth at the other end. The tube is filled with mercury, the stopcock being closed, inverted in the mercury trough, so that the funnel-shaped mouth is upwards, and the water residue is introduced into the funnel and run into the tube, the vessel in which the residue is contained being rinsed with water, and then 3 or 4 c.c. of strong sulphuric acid (free from nitro-compounds) are introduced into the funnel and tube. Care must be taken to avoid the introduction of air into the tube, which is now closed, whilst in the trough, by means of the thumb. The tube is now removed from the trough and vigorously shaken by a semi-rotary motion, so as to keep an unbroken column of at least an inch of mercury below the acid liquid. The pressure exerted by the liberated nitric oxide is, as far as possible, resisted by the opposing pressure of the thumb. At the end of five minutes the reaction is completed, the gas is transferred under mercury to a suitable eudiometer, and its volume measured.

Nitrites

These are best determined by meta-phenylene diamine, the hydrochlorate of which may now be purchased in a state of sufficient purity for the analysis. 1 gramme of the salt is dissolved in 200 c.c. of water acidulated with sulphuric acid. The other solutions required are—dilute sulphuric acid (1 vol. acid to 2 vol. water), and a solution of nitrite of potassium. This solution is prepared by dissolving 0·405 gramme recrystallised nitrite of silver in hot water, precipitating with a slight excess of chloride of potassium, cooling, and making up with distilled water to a litre; allowing the chloride of silver to settle and decanting. For use, 100 c.c. of the clear liquid is diluted with distilled water to a litre. Each 1 c.c. of the diluted solution is the equivalent of 0·01 milligramme of N_2O_3.

To estimate the nitrites 1 c.c. of each of the first two solutions is added to 100 c.c. of the water placed in a nesslerising cylinder, when, if nitrites be present, a yellowish-red colour is produced. This must not be deeper than a just clearly recognisable tint: if deeper than this, a smaller quantity of the water than 100 c.c. must be taken and diluted with distilled water to this volume. The tint is compared with that given by a definite quantity of the standard solution of nitrite made up to 100 c.c. and treated with 1 c.c. each of the meta-phenylene diamine solution and the dilute sulphuric acid. Supposing 100 c.c. of the water gives the same tint as 9 c.c. of the standard nitrite solution in 100 c.c. of liquid: then $0·01 \times 9 = 0·09$ milligramme N_2O_3 in the 100 c.c. and $0·09 \times ·7 = 0·063$ grain N_2O_3 per gallon. The $N_2O_3 \times 0·37 = N$: thus the above water contained $0·063 \times 0·37 = 0·023$ grain N as N_2O_3.

per gallon. This test is not readily applicable when the water is coloured, as, e.g., with peaty matter.

Dr. Thresh has recently devised a method of determining the quantity of nitrites in water by means of iodide of potassium in an atmosphere of coal gas, and titrating the liberated iodine by means of thiosulphate (hyposulphite) of sodium and starch. The apparatus used is the one which he has devised for the estimation of free oxygen in waters. According to Dr. Thresh, the results obtained are accurate ('Jour. Chem. Soc.' vol. 57, 1890, Trans. p. 185).

Ammonia

See 'The Albuminoid Ammonia Process,' p. 285.

Organic Matter

This is the most important constituent to be determined from a sanitary point of view, and the one as to which the most serious discrepancies of opinion have existed. There are three chief methods of estimating organic matter in water, or rather of estimating the relative quantities in different waters; for few will claim that any known method will estimate the absolute quantity of organic matter present. These methods are the combustion process, commonly known as Frankland's, and its modifications; the albuminoid ammonia process, devised by Mr. Wanklyn; and Forchammer's permanganate process. Recently, a new method, that of Kjeldahl, has been introduced. These methods will now be described.

Frankland's Process.—Dr. Frankland claims for his process that it is the only one which determines with anything like precision the total quantity of organic carbon and organic nitrogen present in a water, i.e. the carbon in forms other than that of carbonates, and the nitrogen in other forms than those of ammonia, nitrites, or nitrates; and hence that it affords a measure of the carbon and nitrogen present in the organic compounds present, and so, indirectly, of the absolute quantity of organic matter in a water. In this process the organic carbon is oxidised and obtained as carbon dioxide, and the organic nitrogen is liberated in the free gaseous state and measured. It is further claimed that the proportion of organic carbon to organic nitrogen enables the analyst to judge as to whether the organic matter is of vegetable or animal origin, since animal matters as a rule are richer in nitrogen than vegetable matters. But every one of these claims has been vehemently contested.

In the first place, although it is indubitable that when stable carbon compounds, such as quinine and sugar, are added to a water, the carbon in the latter and the carbon and nitrogen in the former can be determined by the Frankland combustion process with a reasonable amount of accuracy, it is by no means certain that the minute quantities of carbon and nitrogen present in sewage can be determined with anything like the same amount of precision; and it is possible that, during the necessary evaporation to dryness of a large volume of water, unstable and readily decomposable bodies may undergo decomposition, and be lost so far as analysis is concerned. This criticism has never been satisfactorily refuted; and although in a great majority of instances it may have no value, it is probable that in some instances it may have greatf orce. As to the value of the assertion that a higher proportion of nitrogen to carbon is found in animal as compared with vegetable matter, the whole validity of the comparison based on the ratios of these two elements present rests upon the assumption that the absolute

amounts of carbon and nitrogen are both determined; and, as has been already intimated, this has not been proved. It is remarkable, too, that in sea-water the ratio of organic nitrogen to organic carbon is very high indeed—an asserted characteristic of animal, and assuredly of deleterious, organic matter. Yet it can scarcely be supposed that the organic matter in sea-water is chiefly or entirely noxious animal matter, any more than the organic matter in river-water unpolluted with sewage. Yet the Frankland process would *per se* lead us to suppose that sea-water is dangerously polluted with animal matter. Frankland's organic-combustion process is one which requires great care and exactitude in its execution. It cannot be entrusted to the hands of any but those accustomed to its working, and skilled in minute gas analysis. Hence it is seldom employed by the Medical Officer of Health. For a full description of its operations we must refer our readers to the description of its author, Dr. Frankland ('Journ. Chem. Soc.' vol. 21, p. 77; 'Sixth Report of Rivers Pollution Commissioners,' p. 501, and 'Water-Analysis:' London, 1890). The outlines of the process are as follows.

A litre of the water is mixed with 30 c.c. of a freshly saturated solution of sulphurous acid, and boiled for a few minutes. Such a solution of sulphurous acid can be readily and rapidly prepared by passing the gas from a syphon of liquefied sulphur dioxide into distilled water; and these syphons are now articles of commerce. By the above treatment the carbonates are decomposed and carbonic acid expelled. When the water contains little or no carbonate, 0·2 gramme of sulphite of sodium are added before evaporation, to ensure the saturation of any sulphuric acid formed during the evaporation to dryness. A few drops of a solution of ferric chloride are also added before evaporation; and thus the whole of the nitrogen existing as nitrates and nitrites is expelled.

The dry residue is mixed with a few grammes of chromate of lead, and the mixture is transferred to a combustion tube sealed at one end. The remainder of the tube is then charged with cupric oxide and copper turnings in the manner usually followed in making an organic combustion. The open end of the tube is then drawn out in the blowpipe flame, and connected with a Sprengel's mercury pump by means of a piece of caoutchouc tubing, and the connection immersed in a vessel of water. The front part of the tube is then heated, and the pump worked for five or ten minutes until a good vacuum is obtained. An inverted glass tube, filled with mercury, is now placed over the delivery end of the tube of the pump to collect the gaseous products, and the combustion is made in the ordinary manner, an hour being usually taken for the operation, when it will be found that unless much organic matter is present in the water no gas will have passed into the collecting-tube; and the pump has to be again worked for five or ten minutes to transfer the gas into the collecting-tube. The quantities of carbonic acid and nitrogen gases are then respectively determined in the gaseous mixture by the ordinary process of gas analysis. The quantities of gases thus obtained represent the organic carbon and organic nitrogen and the nitrogen of ammonia present in a litre of water. The ammonia is separately determined (see p. 286), and the corresponding quantity of nitrogen deducted from the total combined nitrogen.

For correction for errors of manipulation and apparatus we must refer our readers to the original paper; and, indeed, no unskilled analyst, nor anyone unaccustomed to the necessary manipulations and the sources of error, should undertake to perform an analysis by the Frankland combustion process—an operation at all times requiring great delicacy of manipulation.

Dupré and Hake ('Journ. Chem. Soc.' 1879, p. 159) have simplified the

combustion process, without sacrificing its delicacy and accuracy. An appropriate quantity of the water to be analysed is evaporated to dryness after acidification with phosphoric acid, and the residue transferred to a platinum boat and then placed in a combustion tube 24 inches in length, prepared as follows :—The tube is filled for half its length with granulated cupric oxide, which is kept in position by an asbestos plug. The tube is then drawn out and bent downwards in front to an angle of 120°, and is then attached to a Pettenkofer's absorption tube charged with baryta-water, the other being attached by means of a flexible tube to a reservoir of oxygen gas. The tube is heated to redness, whilst a stream of oxygen is passed through it until the issuing gas ceases to render the baryta-water turbid. The posterior end of the tube is now opened and the platinum boat containing the water residue is quickly inserted. Another Pettenkofer's tube charged with a 2 per cent. solution of subacetate of lead is changed for the baryta-water tube; and the combustion is then made in a stream of oxygen. Finally, the turbidity produced by the carbon dioxide evolved is compared with that produced in the subacetate of lead solution by a known and comparable quantity of carbon dioxide in a modified Mill's colorimeter. For details we refer to the original paper.

Kjeldahl's Method.—This has been recently used for the determination of the total combined nitrogen, except nitrates, in natural waters (Drown and Martin, 'Chemical News,' 1889, vol. 59, p. 272). It is employed as follows: 500 c.c. of the water are placed in a round-bottomed flask of about 30 oz. or 900 c.c. capacity attached to a condenser, and 200 c.c. are distilled and nesslerised for ammonia, as in the albuminoid ammonia process. To the remaining 300 c.c. of water in the flask, after cooling, 10 c.c. of nitrogen-free sulphuric acid are added, and the whole gently agitated so that the acid may mix with the water. The flask is then placed at an inclination on wire gauze on an appropriate support, and the liquid is boiled down till the oily residue is colourless or pale yellow in tint. The flask is removed from the flame, and a very little powdered permanganate of potassium is added till the green colour of the liquid shows that an excess of permanganate has been added. Should the liquid become purple and not green, the water has not been all driven off. After cooling, 200 c.c. of ammonia-free distilled water are added, the neck of the flask being washed free from acid by the process, and then 100 c.c. of a solution prepared by dissolving 200 grammes of good caustic soda in 1250 c.c. of distilled water, adding 2 grammes of permanganate of potassium to oxidise organic matter, and boiling down to a litre. After the addition of this solution, the flask is immediately connected with the condenser, shaken, and the distillation slowly commenced till 50 c.c. have distilled over and been condensed in very dilute hydrochloric acid, after which the liquid in the flask may be vigorously boiled until 150 c.c. or 175 c.c. have been altogether collected. The distillate is made up to 250 c.c. with ammonia-free water, and 50 c.c. of this are nesslerised. It may be necessary to dilute still further before nesslerising. It is not found that with the extreme dilution of natural waters the determination of organic nitrogen is vitiated by the presence of nitrates and nitrites.

The Albuminoid Ammonia Process.—This process was devised by Mr. Wanklyn and the late Mr. E. T. Chapman. It is the process most generally used in the analysis of water for sanitary purposes; and though it does not determine the total amount of organic matter or nitrogenous organic impurity present, it affords perhaps as accurate a comparative estimate of the organic contamination of a water as any other chemical method. Reagents required:—

1. *Nessler's reagent*, prepared by dissolving 35 grammes of iodide of potassium and 13 grammes of mercuric chloride in 800 c.c. of boiling distilled water, and then adding a cold saturated solution of mercuric chloride until a permanent red precipitate begins to form; 160 grammes of solid caustic potash are added, and, when dissolved, the whole is made up with distilled water to the volume of a litre. A little more solution of mercuric chloride is then added to make the solution more sensitive, and it is then allowed to settle. It should have, when clear, a slight yellow colour; if not, it is less sensitive, and requires a further addition of mercuric chloride. The reagent is best kept in a large carefully-stoppered bottle, and a little of the solution is transferred from time to time to a small reagent bottle as required.

2. *Ammonia.*—3·15 grammes of chloride of ammonium are dissolved in a litre of distilled water, and from this a weaker solution is prepared by making up 10 c.c. of the solution to a litre with distilled water. Each 1 c.c. of the weaker solution = $\frac{1}{100}$th milligramme NH_3.

3. *Alkalised Permanganate of Potassium.*—Eight grammes of permanganate of potassium are dissolved in a litre of water; 200 grammes of stick potash are added, and the whole is boiled briskly for half an hour or more, till about one-fourth of the solution is evaporated. The solution is then made up to a litre with ammonia-free distilled water. Or the above quantities of permanganate and caustic potash are dissolved in 1250 c.c. of distilled water and the solution boiled down rapidly to 1000 c.c.

4. *Ammonia-free Water.*—This is prepared by distilling good tap-water, with the addition of a little freshly ignited sodium carbonate, taking care to reject the first portions of the distillate, and not to distil too low. Or, as recommended by the Society of Public Analysts, the purest distilled water obtainable to which one part per 1000 of freshly ignited pure sodium carbonate has been added is boiled briskly until at least one-fourth has been evaporated; 100 c.c. of this water must, when tested, not contain so much as $\frac{1}{200}$th milligramme of NH_3.

The apparatus required are, a stoppered retort holding about 1200 c.c., fitted to a Liebig's condenser, with Bunsen's burner and retort-clamp, several glass cylinders marked at 50 c.c., a half-litre measuring flask, a 50 c.c. glass measure, a funnel by which to fill the retort, a pipette to deliver 2 c.c., and a graduated stoppered burette or pipette graduated to $\frac{1}{10}$th or $\frac{1}{5}$th cubic centimetre. The appropriate apparatus can be readily purchased of the instrument makers in a state of readiness for use. A sink and abundant supply of condensing water is indispensable. In well-appointed laboratories the retort is kept mounted and ready for use.

The operation is conducted as follows: After having cleaned the retort by rinsing it with strong sulphuric acid and then with water, it is mounted, and good tap-water is distilled from it till the distillate comes over free from ammonia; and the retort is then emptied by means of a syphon. Half a litre of the water to be analysed is then introduced through the funnel, and if the water be not alkaline about half a gramme of freshly ignited sodium carbonate is added, and a few pieces of freshly ignited pumice. The retort is then heated and kept boiling by the naked flame of a Bunsen's burner. Successive 50 c.cs. of distillate are collected in the cylinders and 'nesslerised' in the manner to be presently described. The distillation is stopped when no more ammonia comes over. (Mr. Wanklyn prefers to nesslerise the first 50 c.c., which he states always contains three-fourths of the whole ammonia, and then he distils a further 150 c.c., which he rejects.) The ammonia thus obtained is termed 'saline ammonia,' or by

some 'free ammonia.' It represents the ready-formed ammonia, or its salts, present in the water. 50 c.c. of the alkalised permanganate of potassium are now introduced into the retort and the distillation recommenced. A bold application of the gas flame to the naked retort is the best means of avoiding the bumping which often occurs, especially when the water is a bad one. Successive 50 c.cs. of distillate are collected in the cylinders and nesslerised, and the distillation is continued till no more ammonia is evolved. In the case of peaty waters an addition of ammonia-free water, and repeated distillation, may be necessary. When the distillation is completed it is best to leave the retort unemptied, and when a fresh analysis has to be made the retort is washed out *in situ* with tap-water and some of this distilled in the apparatus, which is thus most readily rendered free from ammonia. The ammonia liberated by the alkalised permanganate is termed 'organic ammonia' or 'albuminoid ammonia.' It is the measure of the nitrogenous organic matter present in the water, which is broken up and made to yield ammonia by the alkalised permanganate. To nesslerise ammonia—saline or organic—to a 50 c.c. cylinder of distillate, 2 c.c. of Nessler's solution are added by means of the pipette, and the mixture stirred. The depth of yellow-brown colour is judged of by the eye, and, the requisite amount of ammonia being guessed, a like quantity is run into another cylinder from the burette containing the standard ammonia solution, and the solution diluted till it measures 50 c.c., when 2 c.c. of Nessler's solution is added. The two cylinders are compared, and if the depth of tint is not the same, another cylinder is prepared containing less or more ammonia, as the case may be, till a standard cylinder and the cylinder of distillate agree in tint. With a practised operator the requisite tint is speedily obtained. Should the Nessler's solution give a precipitate with the distillate, it is requisite to repeat the distillation, and take smaller quantities of the distillate—10 c.c. or 20 c.c., and dilute to 50 c.c. before nesslerising. Each 1 c.c. of standard ammonia solution containing $\frac{1}{100}$th milligramme of NH_3 will, of course, represent that quantity in the 500 c.c. of water taken, or ·02 part per million, or 0·0014 grain per gallon. Thus, e.g.—500 c.c. of water yielded successive distillates of 50 c.c., which, when nesslerised, gave a tint equal to 1·5 c.c., 0·5 c.c., and 0·0 c.c. of standard ammonia, and of albuminoid ammonia equal to 3 c.c., 2 c.c., 1 c.c., 0·5 c.c., and 0·0 c.c. standard ammonia solution. Then we have:—

Saline, NH_3.—$1·5 + ·5 = 2 \times 2 = 4$ — 100th milligramme per litre NH_3, or ·04 part per million; and $·04 \times ·07 = ·0028$ grain per gallon.

Albuminoid, NH_3.—$3 + 2 + 1 + 0·5 = 6·5 \times 2 = 13$ — 100th milligramme per litre, or 0·13 per million; and $·13 \times ·07 = ·0091$ grain per gallon.

The advantages of the albuminoid ammonia process are, the rapidity with which it is carried out, the simplicity of the apparatus required, and, what its defenders assert, the greater certainty of its results when compared with those obtained by any other process. It is not pretended that the nitrogen yielded in the form of albuminoid ammonia is all that contained in the water operated on; Mr. Wanklyn, indeed, asserts that the nitrogen obtained is a definite fraction of that contained in many organic bodies, but even this can scarcely be asserted of the unknown forms of nitrogenous organic matter contained in waters. Its detractors aver, on the other hand, that the albuminoid ammonia yielded is uncertain in its amount, and is no definite guide to the organic nitrogen present in a water; and that it is misleading. Probably the truth is, that neither is the albuminoid ammonia a certain index to the quality of a water, nor an altogether unreliable one. Generally, it is fairly reliable, and no more can be asserted with assuredness of any other process for determining the pollution of a water.

The behaviour of peaty waters when submitted to the albuminoid ammonia process is peculiar. They yield a relatively large quantity of albuminoid ammonia, which is evolved slowly and somewhat persistently. This peculiarity is so well known that it can scarcely mislead any skilled analyst accustomed to use the process. Badly polluted waters, on the other hand, generally yielded their high proportion of albuminoid ammonia promptly and sharply.

The Permanganate Process for Determination of Oxygen required to Oxidise Organic Matter.—This process is carried out in various ways. The following is the method as advised by Dr. Tidy, who has specially investigated the process ('Jour. of Chem. Soc. Trans.,' vol. xxxv., 1879, p. 46).

The following solutions are required (for the quantities given by Dr. Tidy in grains and septems are substituted grammes and cubic centimetres):

1. Dilute sulphuric acid: 1 part of pure sulphuric acid with 3 parts of distilled water.

2. Solution of permanganate of potassium: 0·286 gramme per litre; 10 c.c. = ·714 milligramme of available oxygen.

3. Solution of iodide of potassium, free from iodate: 1 part in 10 parts of water.

4. Thiosulphate of sodium (hyposulphite): 0·77 gramme in a litre of distilled water.

5. Starch solution, carefully prepared: about $1\frac{1}{3}$ gramme in 100 c.c. of water.

Two similar pint-glass flasks are very carefully cleaned, and in each is placed 250 c.c. of the water to be analysed, 10 c.c. of dilute sulphuric acid, and 10 c.c. of the permanganate solution, noting the time of adding the permanganate. If before the end of three hours the colour of the permanganate has disappeared, a second or even a third addition of 10 c.c. of permanganate must be made, so as to maintain the red colour of the liquid in the flask. At the same time as the above experiments are made, two similar quantities of distilled water are treated in a precisely similar manner. At the end of one hour, and at the end of three hours, one of each of the flasks containing distilled water and the water under examination respectively is treated with two drops of the iodide of potassium solution, and then titrated with the thiosulphate solution. The other two flasks—one of distilled water, and the other of the sample water—are allowed to remain till the reaction with the permanganate has gone on for three hours, and then two drops of the iodide solution are added, and the titration with thiosulphate ('hypo') completed.

The value of the thiosulphate solution must be very frequently determined, as the salt decomposes in solution. A blank experiment with distilled water is made by putting 250 c.c. of distilled water into a flask, with 10 c.c. of dilute sulphuric acid and 10 c.c. of the permanganate solution. Two drops of the iodide of potassium solution are added, and then the thiosulphate solution is run in from a burette until the yellow colour of free iodine has nearly disappeared. A few drops of the starch solution are now added, and the addition of thiosulphate continued till the blue colour just disappears; and the amount of the thiosulphate used is noted. In operating upon the water under analysis, the same process of titrating with thiosulphate is followed after one and three hours' action of the permanganate.

The calculation of the results is as follows:

Let X = no. of c.cs. of thiosulphate used in the distilled water.

Y = no. of c.cs. of thiosulphate used in the water under examination.

Then if 10 c.c. of the permanganate solution were used,

$\frac{X - Y \times 0{\cdot}2}{X}$ = grains of oxygen required to oxidise organic matter in one gallon of the water.

If 20 c.c. of permanganate were used, 2X must be substituted for X in the above equation; if 30 c.c. substitute 3X, and so on, in making the calculation.

The method recommended by the Society of Public Analysts ('The Analyst,' vol. vi., 1881, p. 126) of carrying out the operation is somewhat different, and is performed thus:—

Two separate determinations are made—the amount of oxygen absorbed during fifteen minutes, and that absorbed during four hours; both being made at a temperature of 80° F. (26°·7 C.). These are made in 12 oz. stoppered bottles. Put 250 c.c. of the water into each of two of the bottles; stopper and immerse in a water-bath until the temperature reaches 80° F. Now add to the water 10 c.c. of dilute sulphuric acid (1–3), and 10 c.c. of a solution of permanganate of potassium (0·395 gramme per litre). Fifteen minutes after the addition of the permanganate, one of the bottles is removed from the bath, 2 or 3 drops of a solution of iodide of potassium (1 in 10) added, and the liberated iodine titrated by means of a solution of thiosulphate (1 gramme in 1 litre of water), the end of the reaction being determined by a solution of starch (1 in 500), as in Dr. Tidy's process. At the end of four hours the other bottle of water is titrated in the same manner. But if before the expiration of four hours the pink colour of the solution should grow very pale, a further addition of a measured quantity of the permanganate solution must be made, so as to keep up a decided pink or red colour. The thiosulphate solution must be titrated with 250 c.c. of good distilled water from time to time, into which is placed 10 c.c. of the permanganate solution, and then a few drops of the iodide of potassium solution. The quantity used will represent the quantity of thiosulphate solution equivalent to 0·00395 gramme permanganate, or ·001 of available oxygen. The calculation is this.

Let a = number of c.cs. thiosulphate required in blank experiment to = 10 c.c. permanganate.

b = number of c c. thiosulphate used in titration of the water.

Then $\frac{a - b \times {\cdot}28}{a}$ = grains of oxygen per gallon required to oxidise organic matter.

Recently Mr. Blair has proposed a novel method of estimating the amount of organic matter in drinking water; but his process has not as yet been much adopted ('The Organic Analysis of Potable Waters,' by J. A. Blair, M.B., 1890).

Lead and Copper.—An examination for these injurious metals may be readily and expeditiously made; and if one of these metals only be present, as is usually the case, by calorimetric methods.

100 c.c. of the water is placed in a nesslerising cylinder, and a drop of solution of sulphide of ammonium is stirred in, when a dark colouration or precipitate will indicate the presence of iron, lead, or copper. If it be due to iron, the colour will be discharged by the subsequent addition of a drop or two of strong hydrochloric acid, which will not, however, discharge the colour if lead or copper be present.

Copper may be distinguished from lead by placing 100 c.c. of the water in a similar cylinder, acidifying with a drop or two of acetic acid and a drop of a solution of ferrocyanide of potassium, when, if copper be present, the liquid will acquire a faint red tint. By comparing the depth of tint with

distilled water similarly treated, and to which a standard solution of sulphate of copper has been added, the quantity of copper may be estimated. A convenient solution for this purpose is an aqueous solution of crystallised sulphate of copper, 5·6 grammes to the litre: 1 c.c. of this solution contains 1·43 milligramme of copper; and hence, working with 100 c.c. of water, each 0·1 c.c. copper solution added to the water corresponds to 0·1 grain copper per gallon.

The presence of lead may be confirmed by placing some of the water in a tall glass cylinder and sprinkling on its surface a few fragments of powdered potassium bichromate, when, if lead be present, a cloud of yellow lead chromate will fall in streaks to the bottom of the cylinder. The quantity of lead may be determined by treating 100 c.c. of the water in a cylinder as in the titration of copper, adding a drop of hydrochloric acid and 2 c.c. of good sulphuretted hydrogen water. The depth of brown or black colour produced is then compared with that produced by the same quantity of the same reagents, added to 100 c.c. distilled water in a similar cylinder. The standard lead solution employed should contain 2·62 grammes crystallised lead acetate, and a few drops of acetic acid in a litre of distilled water. Each 1 c.c. contains 1·43 milligramme of lead; and when 100 c.c. of water are operated on, each 0·1 c.c. corresponds to 0·1 grain of lead per gallon.

Hardness.—For hygienic purposes it is always desirable to estimate the hardness of a water, i.e. its soap-destroying capacity; and although it is undoubted that the hardness of a water, as determined by experiment, is not always a safe guide to the quantity of lime and magnesia salts present—these being the chief soap-destroying constituents of ordinary waters—an estimate of the so-called hardness of a water by Clark's soap test ought never to be omitted.

A hard water is one which requires much soap in order to yield a permanent lather, and is usually rich in lime and magnesia salts; a soft water is, conversely, one usually poor in the salts of the alkaline earths, and readily yields a lather with a small quantity of soap. Again, the hardness of a water is distinguished as *total hardness* or the hardness of the natural water; *permanent hardness*, or that which remains after boiling, and chiefly due to the presence of those salts of calcium and magnesium—such as the sulphates, chlorides, and nitrates—which are not thrown down on boiling; and *temporary hardness*, obtained by subtracting the permanent from the total hardness, and attributable to the carbonates of calcium and magnesium present. These definitions are, nevertheless, not strictly accurate; for hardness may be due to the presence of ferruginous salts, and permanent hardness may be due, in the absence of temporary hardness, to the existence of free mineral or vegetable acids in the water; for acids destroy soap equally with lime compounds. It is hence best to consider hardness strictly and solely as soap-destroying power, to whatever cause this be assignable.

Dr. Clark, of Aberdeen, first proposed a method of determining hardness experimentally, in substitution of the method of computing the hardness from the amounts of lime and magnesia found by analysis, and his method, or a modification of it, is now universally adopted ('On the Examination of Water for Towns for its Hardness,' by G. T. Clark, 1847).

When a solution of soap—best in dilute alcohol—is added to distilled water, and the whole is agitated, a faint opalescence appears, and at first no lather forms; but the addition of a very small further quantity of the soap solution results in the formation of a permanent lather on agitation. But if an ordinary hard water be treated in the same manner, the opalescence

becomes a marked turbidity or distinct precipitate, and much more soap solution has to be added to procure a permanent lather, which appearance indicates the presence of a slight excess of soap—conferring viscosity to the liquid—beyond the amount necessary to decompose the lime and magnesia salts, and other soap-destroying compounds present; nor does the test directly distinguish between one soap-destroying compound and another.

It is customary to express the hardness in 'degrees;' and each degree of Clark's scale indicates one grain of calcium carbonate per gallon of water, or the equivalent of one grain of chalk in soap-destroying power. Thus, *e.g.*, one degree of hardness may be due to one grain of calcium carbonate, 1·11 grain of calcium chloride, or 1·36 grain of calcium sulphate, &c., each of these calcium compounds containing in the above quantities respectively 0·4 grain of calcium. In France each degree of hardness indicates one part by weight of calcium carbonate, or its equivalent, per 100,000 parts of water; whilst in Germany a degree of hardness indicates one part of *lime* (CaO), or its equivalent, per 100,000 parts of water. Hence the various values of degrees of hardness are:—English 1° = German 0°·8 = French 1°·4 nearly. Many analysts who give the results of their analyses in parts per 100,000 use the French scale of hardness.

The requisites for the determination of hardness:—

1. A standard solution of calcium sulphate is obtained by grinding in a mortar 0·1965 gramme of crystallised selenite, $CaSO_4$ $2H_2O$, with a sufficiency of distilled water to dissolve it, and making up to the volume of a litre. Or 0·2985 gramme barium nitrate may be dissolved in distilled water and made up to a litre. Either of these solutions contains the equivalent, in calcium or barium salts, of 8 grains calcium carbonate per gallon.

2. A stoppered narrow-mouthed bottle holding 200 c.c., or, as preferred by some, one holding 100 c.c.

3. A burette on stand divided into cubic centimetres and tenths of a cubic centimetre.

4. The standard soap solution. A potash soap is best for the desired purpose, prepared thus: 15 parts of the lead plaster of the British Pharmacopœia (lead oleate) are warmed on a water-bath with 4 parts of potassium carbonate and rubbed in a mortar to a uniform consistence; then digested with ordinary rectified methylated spirit, allowed to deposit, and diluted with water in the proportion of three volumes of water to every five volumes of rectified spirit employed; in other words, the alcohol is reduced to about proof strength, and any subsequent dilution is made with spirit of proof strength. The solution is then filtered.

Very commonly the soap solution is prepared by dissolving ordinary good undried Castile soap in the proportion of 14 grammes to the litre of a mixture of methylated rectified spirit and distilled water in equal volumes; and there is no objection to this when no minute degree of accuracy is demanded. In any case it is well to prepare a stock bottle of strong soap solution, and to dilute some of the clear liquid from time to time with alcohol of proof strength and standardise it in the following manner occasionally, as soap solutions are apt to deposit in winter, or when long kept, and thus to lose strength.

The standardising of the soap solution is effected by taking 50 c.c. of the standard calcium (or barium) solution, placing it in the bottle and running in the soap solution from a burette till a thick fine uniform white froth is produced on vigorously shaking the bottle, and should remain for five minutes when the bottle is placed on its side. If less than 9 c.c. of the soap solution are required, the requisite quantity of dilute alcohol is added to reduce

it to the required strength, i.e. so that 9 c.c. of the soap is exactly sufficient to give a permanent lather with 50 c.c. of the standard calcium solution of 8·0° of hardness. For example, 50 c.c. of the standard calcium gave a lather persisting for five minutes with 6 c.c. of a soap solution; then each litre of this soap solution must be diluted till it measures $\frac{9}{6}$ths of a litre, or 1500 c.c. The solution after this adjustment must be again titrated, and if 50 c.c. of the standard water requires more or less than the requisite 9 c.c., a little more dilute alcohol, or a little strong solution of soap must be added till the requisite strength is obtained.

The estimation of hardness is effected by pipetting 50 c.c. of the water into the stoppered bottle, and running in the standard soap solution from the burette, at first rapidly, and then very slowly, with repeated shaking till a fine uniform creamy lather is obtained, which persists for five minutes, when the bottle is allowed to rest on its side. An approximation to the quantity of soap required being thus obtained, the titration is repeated with greater care, adding the soap at first in quantities of 1 c.c. at a time, and towards the end of the reaction drop by drop till the desired lather is obtained. The carbonic acid liberated on agitation should from time to time be removed by blowing air into the bottle by a pair of bellows.

Should more than 9 c.c. of soap be required, it is always well—and in the case of magnesian waters indispensable—to dilute the water under examination with its own bulk, twice its own bulk, &c., of distilled water till not more than 9 c.c. is required by 50 c.c. of the diluted water.

The proportion between the soap used and the actual degree of hardness of a water is not constant, and, according to the accurate observations of Faiszt and Knausz, the degree of hardness corresponding to each 1 c.c. of soap solution used increases constantly with the amount of soap used. According to Wanklyn, distilled water requires 1 c.c. of soap solution to produce a lather; and he deducts 1 c.c. from the number of cubic centimetres of soap solution, and the remainder gives the hardness in degrees. The later experiments of Clark, confirmed by those of Faiszt and Knausz, give 0·5 c.c. approximately, as the amount of soap required by 50 c.c. of distilled water. The following table expresses Clark's latest results, and is sufficiently accurate:

C.c. of soap solution used.	Degrees of hardness (Clark).
0·45	0°
1·45	1°
2·70	2°
3·85	3°
4·95	4°
6·00	5°

After which deduct 1 c.c. from the number of c.cs. used, and the remainder is the hardness in degrees.

In this way, the *total hardness* having been determined, 250 c.c. of the water is kept boiling over a naked flame for half an hour or an hour, the evaporated water being *nearly* replaced from time to time by distilled water. The water is quickly filtered into a dry 250 c.c. flask, the filter quickly washed with boiling distilled water, and the whole adjusted to 250 c.cs. when cold. 50 c.c. of the boiled water is then titrated anew with soap solution, and in this way the *permanent hardness* is obtained. The difference between total and permanent gives the *temporary hardness*.

It must not be forgotten that if the water be diluted the necessary correction for dilution must be made.

The following are useful data as to hardness:

1 degree (1°) Clark's scale = 1·4 degree (1°·4) on the centesimal scale (parts per 100,000).

1 degree (1°) Clark's scale = 0·8 degree (0°·8) on the German scale.

1 grain $CaCO_3$ = 1·11 gr. $CaCl_2$ = 1·38 gr. $CaSO_4$ = 0·56 gr. CaO = 0·84 gr. Mg CO_3 = 0·4 gr. Mg O in soap-destroying power.

1 grain per gallon $CaCO_3$ = 1·43 milligramme per litre.

Distilled water requires approximately as much soap to yield a lather as 0·7 grain per gallon $CaCO_3$, or 1 part $CaCO_3$ in 100,000 parts of water. This is the excess of soap beyond that required to precipitate the calcareous salts of the water required to produce a lather on agitation of the water with the soap.

Iron.—It is not often necessary for sanitary purposes to determine the quantity of iron present in a drinking water. Generally it is sufficient to ascertain that a water is not chalybeate by the sense of taste, and by ascertaining that it does not assume a purple or inky hue on the addition of a few drops of tincture of galls to half a pint of the sample. But when it is desired to ascertain the amount of iron present, this can be most conveniently done by making use of a process devised by Carnelley ('Mem. Manchester Lit. and Phil. Soc.' 1874–5, p. 346). 1 c.c. of dilute sulphuric acid is added to a measured volume of the water, to which a dilute solution of permanganate of potassium is added until a permanent pink tint is imparted to the liquid; and the volume is then made up to a litre by the addition of distilled water. The quantity of the water under examination requisite to make up the litre is judged of approximately by previous qualitative tests for iron. 50 or 100 c.c. of the litre of liquid thus obtained are placed in a cylinder, 5 c.c. of dilute nitric acid are added, and then a couple of drops of a solution of potassium ferrocyanide. The depth of blue colour (Prussian blue) produced is then compared with that produced under like conditions in a similar cylinder by a standard solution of iron when mixed with the same quantities of the dilute nitric acid and ferrocyanide solutions. The iron (ferric salt) solution is prepared by dissolving 0·7 gramme of pure crystallised ferrous ammonium sulphate in water, acidulating with 1 c.c. of dilute sulphuric acid, oxidising by the addition of a solution of potassium permanganate till a barely visible permanent rose tint is produced, and diluting with distilled water to a litre. 1 c.c. of this solution = 0·1 milligramme of iron.

For example: 500 c.c. of a water was oxidised with permanganate and made up to 1 litre. Of this 50 c.c. gave as much blue colour with ferrocyanide as 0·5 c.c. of the standard iron solution in 50 c.c. of distilled water. Then $0·5 \times 0·1 \times 20 = 1$ milligramme is the quantity of iron in 500 c.c. of the water under examination; and $1 \times ·2 = 0·2$ is the iron per 100,000 parts; and $1 \times 0·14 = 0·14$ is the grains of iron per gallon.

In operating upon chalybeate waters greater dilution is necessary; but the results are sufficiently accurate for all ordinary purposes.

Silica.—A litre of the water is acidified with hydrochloric acid, and evaporated to dryness in a platinum dish, the residue digested with strong hydrochloric acid in a warm place, water added to the separated silica, which is filtered off, well washed, dried, ignited, and weighed.

Manganese.—This metal is rarely present in waters in appreciable quantity, though its presence was formerly not at all uncommon in the acid waters contaminated by the discharge from bleach-works. Manganese may be detected by concentrating the water, precipitating with ammonia and a few drops

of a solution of peroxide of hydrogen, and collecting the precipitate of ferric, aluminic, and manganic oxides on a filter. The washed and dried precipitate with the filter is fused with caustic soda and a fragment of potassium nitrate in a silver dish, when the manganese is converted into a manganate. On treating the residue with water faintly acidulated with sulphuric acid, a rose-red or purple solution of permanganic acid is obtained, which when examined by the spectroscope exhibits fine dark characteristic absorption bands, and is decolourised by the addition of a drop or two of ammonium oxalate solution.

A quantitative determination of the manganese is seldom or never required in the hygienic analysis of a water.

Chromium.—Compounds of chromium (chromic salts and chromates) may be detected by evaporating a litre or two of the water to dryness, and fusing the dry residue with sodium carbonate and a fragment of potassium nitrate in a silver dish. The residue is extracted with water, filtered, and the filtrate neutralised with nitric acid and evaporated twice to dryness in a porcelain dish, in order to get rid of free nitric acid. The neutral residue dissolved in water will, if chromium be present, yield a yellow precipitate insoluble in acetic acid when solution of lead acetate is added, and will also yield a red precipitate of silver chromate if *excess* of silver nitrate solution be added.

A water containing chromium compounds should be unhesitatingly rejected as a drinking-water, these compounds being highly irritant and toxic, even in minute quantities.

Dissolved Oxygen.—Dr. Thresh ('Proc. Chem. Soc.' 1890, p. 1) has devised the simplest method of estimating the dissolved oxygen gas in water.

The solutions required for the process are: (1) a solution containing 0·5 gramme sodium nitrite and 20 grammes potassium iodide in 100 c.c. distilled water; (2) an aqueous solution containing 7·75 grammes sodium thiosulphate (hyposulphite) to the litre. 1 c.c. of this corresponds to 0·25 milligramme of oxygen; (3) clear starch solution; (4) dilute sulphuric acid (1 : 3). The apparatus used consists of a wide-mouthed bottle of 500 c.c. capacity, provided with a caoutchouc stopper through which four holes are bored. Through one passes the neck of a cylindrical 'separator' funnel of known capacity, and through the second a tube drawn out to a fine point, which is connected by a short length of flexible tubing with the thiosulphate burette, while inlet and exit tubes for coal-gas are passed through the third and fourth holes, the exit tube having attached to it a sufficient length of caoutchouc tubing to permit of connection being established between the bottle and the separator when the stopper of the latter is withdrawn.

The separator is filled with the water to be examined, and 1 c.c. of the nitrite-iodide, and 1 c.c. of the acid solution are added. If the pipette be held vertically, with its end just below the surface of the water, the solutions flow in a sharply defined column to the lower part of the separator; so that a very small quantity, if any, is lost in the water which overflows when the stopper is inserted. The apparatus is inverted several times, and then a quick current of coal-gas is passed through the bottle, the escaping gas being ignited. After fifteen minutes the flame is extinguished; a cork is attached in place of the jet, and is inserted in place of the stopper of the separator; and the water is then allowed to flow into the bottle. The exit tube having been disconnected from the funnel and the gas lighted, thiosulphate is run in until the colour of the iodine is nearly destroyed; about 1 c.c. of starch solution is then added from the separator, and the titration is completed.

The effect of the nitrite, dilute acid, and starch solutions is determined by removing the separator and adding 5 c.c. of each in succession and then titrating. An allowance is made for the oxygen dissolved in it, on the assumption that as much oxygen is dissolved in it as in distilled water at the same temperature. At the temperature of 59° F. (15° C.) distilled water dissolves 7 milligrammes of oxygen per litre.

DETERMINATION OF THE ACTION OF A WATER UPON LEAD

This important determination, where the adoption of a new water-supply is under consideration, is one beset with difficulties; and the results obtained are, as a rule, by no means satisfactory or conclusive.

A method commonly adopted is to immerse fresh-scraped clean plates of lead, 6 × 2 inches in size, in a known volume, say 500 c.c. (or, better, 1 pint = 568 c.c.) of the water in a loosely stoppered bottle capable of holding double this quantity of liquid. After twenty-four hours the strips of lead are removed and any corrosion or deposit is noted. After filtration the water is examined for the lead in the usual manner (see p. 256).

A better and more satisfactory plan is to take a 36-inch length of fresh well-cleaned lead pipe, of $\frac{1}{2}$ inch bore, closed by means of a cork provided with a pinch-cock below, and by a cork above. The tube is rinsed with the water and then filled with it, corked, and placed in an early horizontal position, the pinch-cock being at the lowest end of the tube. After a definite period, say 12, 18, or 24 hours, the water is run out of the tube, and replaced by a fresh quantity, which is again withdrawn at the end of any desired period. The successive quantities of water are measured, and the lead present determined as before. In this way the action of the water upon lead (either fresh pipe or after some use) may be determined. The volume of water held by a pipe of $\frac{1}{2}$ inch bore, and 36 inches in length, is one-fifth of a pint approximately, or 116 c.c.

STANDARD SOLUTIONS, FOR ANALYSIS

The following are the strengths of the standard solutions recommended.

1. *Nitrate of Silver.*—4·79 grammes recrystallised silver nitrate per litre of water. 1 c.c. precipitates 1 milligramme of chlorine.

2. *Indigo Solution* of such strength that 1 c.c.$=\frac{1}{10}$th milligramme N_2O_5 =1 c.c. of a solution of 0·187 gramme KNO_3 per litre of water.

3. *Phenol-sulphuric Acid.*—2 volumes melted absolute phenol, 5 vol. pure oil of vitriol, about 5 vol. distilled water, and $1\frac{1}{2}$ vol. strong solution of HCl (see p. 279).

Potassium nitrate for use with the above, 0·7215 gramme per litre of water.

4. *Metaphenylene-diamine Hydro-chlorate.*—1 gramme in 200 c.c. distilled water, acidulated with sulphuric acid.

Silver nitrite for use with this, 0·405 gramme $AgNO_2$ precipitated with KCl and made up to a litre. This is diluted 10 times for use, when each 1 c.c. $= \frac{1}{100}$th milligramme N_2O_3.

5. *Nessler's Solution.*—35 grammes potassium iodide, 13 grammes mercuric chloride, and 160 grammes caustic potash to a litre. If not sensitive, add more of a solution of mercuric chloride.

6. *Chloride of Ammonium.*—3·15 grammes ammonium chloride to a litre of water. Each 1 c.c. = 1 milligramme NH_3.

A solution prepared by diluting the above 100 times; each 1 c.c. $\frac{1}{100}$th milligramme NH_3.

7. *Alkalised Potassium Permanganate.*—8 grammes potassium permanganate and 200 grammes stick caustic potash in 1250 c.c. distilled water. Boil down to 1 litre.

8. *Potassium Permanganate* for oxygen process, 0·286 gramme per litre of water.

9. *Sodium Hyposulphite.*—0·77 gramme sodium thiosulphate ('hypo') in a litre of water.

10. *Lead Acetate.*—2·62 grammes in a litre of water.

11. *Copper Sulphate.*—5·6 grammes to a litre of water.

12. *Calcium Sulphate* (for hardness).—0·1965 gramme selenite in a litre of water (=8° hardness, Clark's scale). It is used for 'setting' soap solution.

13. *Ferrous Ammonium Sulphate.*—0·7 gramme of the crystallised double salt in a litre of water. Each 1 c.c.=$\frac{1}{10}$ milligramme iron.

14. *Soap Solution.*—9 c.c. give a permanent lather with 50 c.c. of a solution of calcium sulphate ($CaSO_4{\cdot}2H_2O$) containing 0·1965 gramme in a litre of distilled water.

BACTERIOLOGICAL EXAMINATION.

Many, if not most, waters contain bacteria, as was shown by Dr. Burdon Sanderson ('Twelfth Report of Medical Officer of Privy Council,' 1870, p. 229); and there are several methods used for the bacteriological examination of water. These methods have not, however, come into general use, because no means are known which enable the microscopist and analyst to discriminate between pathogenic, zymogenic, and presumably inert bacteria by mere inspection. The bacteria of unwholesome water liquefy gelatine cultivation-media more readily than those from wholesome waters; but this summary embraces most that is known of the subject of the significance of bacteria in drinking-water. Some chemists attach importance to the number of colonies of organisms which may be developed in a cultivation-area by inoculation with the water; but it cannot be said that it is certainly known that there is any definite relation between the number of organisms and the unwholesomeness of the water. To Koch is due the merit of having introduced exact methods of discriminating between various kinds of bacteria.

Dr. Angus Smith's method is a good one for recognising that micro-organisms are present in water, though less useful in determining their characters. It consists in introducing, by means of a capillary sterilised pipette, drops of the fluid into gelatine or gelatine-broth in test tubes plugged with sterilised cotton-wool, and heated to 35°–40° C. (95°–104° F.). The tubes are then shaken so as to distribute the inoculated liquid through the gelatine, which is then allowed to cool and set. After a few days the colonies of organisms that liquefy gelatine may be recognised as clusters disseminated through the gelatine (which they liquefy). The size of the clusters, their appearance and groupings, are then noted. Dr. Percy Frankland ('Proceedings of Royal Society,' vol. xxxviii., 1885, p. 379) and Dr. Warden, of Calcutta ('Chemical News,' vol. lii., 1885, pp. 52, 66, 73, 89, and 101) have published valuable methods of determining the relative numbers of micro-organisms present in waters, by means of plate cultivations. This may be done by adding a measured small quantity of the

water to be examined to a definite quantity of liquefied sterilised nutrient gelatine, in a sterilised test tube. The mixture is well shaken and poured into a glass plate, placed beneath a bell glass in a moist chamber, and kept at a temperature of 70°–72° F. (21°–22° C.). After a few days the number of colonies, their shape, size, colour, and other characters, may be noted.

Dr. Klein ('Micro-organisms and Disease,' 3rd ed., p. 49) recommends the following method for the examination of any sample of water for micro-organisms. The water is allowed to stand for a few hours, till most of the particulate matter has subsided, and then a little of the fluid and sediment is withdrawn by means of a long capillary pipette. Some of the fluid and sediment thus removed is used for microscopic examination whilst fresh; whilst another portion is prepared after the Weigert-Koch method, by spreading out the fluid on a cover-glass in a thin layer, drying it, fixing by passing three times through a flame, staining with a suitable aniline dye, such as methyl-blue, magenta, or gentian-violet; washing successively with water, alcohol, and distilled water; drying, and then mounting the preparation in Canada balsam dissolved in benzene or xylol. Test tubes containing sterilised cultivation material—such as agar-mixture, gelatine, or Pasteur's fluid, are also inoculated with the fluid in the pipette, by piercing the plug of cotton-wool with this. The test tubes are then placed in the incubator for a day or two, and then a portion is withdrawn by means of a capillary pipette, and used for microscopic examination in order to ascertain what kinds of organisms are present; for the unaided eye generally suffices after a day or two's incubation to ascertain whether organisms are present or not. New cultivations may also be made from the first cultivation.

The following method of plate cultivation is recommended on good authority ('Crookshank's Manual of Bacteriology,' 2nd ed., pp. 72 and 367). A shallow glass dish is placed on a tripod stand, filled with water, covered with a glass plate, and the level carefully adjusted by means of a spirit-level, which is then removed, and replaced by a piece of filter-paper the size of the glass plates to be used, and then covered with a bell-glass. The glass plates are put into an iron case and sterilised in a hot-air steriliser heated to 150° C. (302° F.), where they are kept for an hour or two. The water in the dish is now cooled by means of crushed ice; a sterilised plate is removed from the box by means of sterilised forceps, held between the finger and thumb by opposite edges, and rapidly transferred to the filter-paper on the glass plate. The vessel containing sterilised gelatine is warmed in a vessel of water heated to 30° C. (86° F.), inoculated with the sample by means of a sterilised pipette, and well mixed by shaking, avoiding the formation of air-bubbles; the bell-glass is raised, and the gelatine is poured on to the plate, the plug being previously removed, and the gelatine is quickly spread over the plate by means of a sterilised glass rod to within half an inch of the border of the plate. The bell-glass is replaced, and the gelatine allowed to set. When quite set, the plate is transferred to the damp chamber.

In two or three days the cultivation may be examined, and the colonies counted; and for this purpose a glass plate ruled into square centimetres, arranged on a frame so that it may be placed over the plate containing the cultivation, may be requisite, so that the number of colonies beneath one square, and the number of liquefying colonies also, may be counted. Individual organisms may then be examined by means of cover-glass preparations, and by further inoculations of nutrient gelatine and other media.

Dr. Dupré ('Report of the Medical Officer,' in 14th Report, 1884, p. 304; 15th Report, 1885, p. 309; and 17th Report, 1887, p. 272, of the Local

Government Board), has investigated the changes effected in the aëration of waters by the life processes of particular micro-organisms under different conditions of temperature, light, and nutrient material; but all that can at present be said is, that some organisms cause the disappearance of oxygen under the influence of organic matter in the light, others only in the dark.

Dr. W. R. Smith in the preliminary report on the Differentiation and Identification of Micro-Organisms found in Water-supplies ('Report of the Medical Officer, 17th Report, 1887,' p. 268) has investigated the micro-organisms in the water supplied by two of the London Water Companies. His method was to make gelatine plate cultivations at 20° C. (68° F.), and agar plate cultures at 30° C. (86° F.); and with the organisms thus developed mice were inoculated; but in no case was any noteworthy result obtained. He did not detect any disease-producing organism, but colonies of microphytes of multifarious character, such as *Bacillus fluorescens liquescens*, *Staplycoccus flavus liquescens*, *Bacillus erythrosporus*, and others whose identity with known organisms was not established. But, whatever method be adopted, the information afforded is at present of very limited value, for (1) all the organisms introduced into the culture medium may not be capable of propagation in this latter; (2) each colony may possibly be the produce of one or more individual organisms, but this is not likely; (3) accidental contamination of a water after collection may readily occur.

CHARACTERISTICS OF GOOD DRINKING-WATER

In their celebrated 'Sixth Report,' the Rivers' Pollution Commissioners made the following weighty remarks:—

'In respect of wholesomeness, palatability, and general fitness for drinking and cooking, our researches lead us to the following classification of waters in the order of their excellence, and founded upon their respective sources.

'Wholesome .	1. Spring water	Very palatable.
	2. Deep-well water	
	3. Upland surface water	Moderately palatable.
'Suspicious .	4. Stored rain water	
	5. Surface water from cultivated land .	Palatable.'
'Dangerous .	6. River water to which sewage gains access	
	7. Shallow-well water	

And they urge that preference should always be given to spring and deep well water for purely domestic purposes, over even upland surface water, not only on account of the much greater intrinsic chemical purity and palatability of these waters, but also because their physical qualities render them peculiarly valuable for domestic supply, since they are almost invariably clear, colourless, transparent and brilliant—qualities which add greatly to their acceptability as beverages; whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer, and prevents them from freezing readily in winter. Their inestimable value to communities in these respects are, however, in some degree neutralised as regards temperature when they have to be stored; and too often the quantities available are inadequate to supply the needs of large communities and too costly. Hence, we find that for large towns, upland surface water-supplies are now being largely adopted; as witness Glasgow from Loch

Katrine, Manchester from Lake Thirlmere, and Liverpool from Lake Vyrnwy. Often, too, it is desirable, and more especially in the case of a manufacturing community, to have not only an organically pure and a palatable, but also a soft water supply; and here the advantage of an upland surface water becomes manifest.

The geological strata through which a spring or deep well water has percolated will greatly influence its palatability. Whilst surface waters are often vapid and tasteless, or have a peaty bitter flavour, in percolating through deep rocky strata, organic matter is oxidised; and such waters are often highly charged with carbonic acid gas, which renders them brisk and palatable. The waters drawn from the deep artesian wells in the Thames basin are often deficient in oxygen, and faintly opalescent. Some, too, contain traces of sulphuretted hydrogen, and require exposure to the air to render them palatable; whilst others, again, when stored become filled with confervoid growths. The spring waters of the magnesian limestone formation are not only excessively hard, but contain such a proportion of magnesian salts as, in the opinion of most authorities, render them unfit for drinking purposes. A pure magnesian water may nevertheless, it is thought by many, form a good water for domestic use. The experience of Sunderland and Bristol is not unfavourable to the use of magnesian waters. The deep well waters of some of the beds of the New Red Sandstone are rich in gypsum as well as in chalk, and, though palatable, are excessively hard.

Various arbitrary standards have been laid down defining the amounts of organic matter, as measured by one or other of its elementary constituents, permissible in drinking-water. All are more or less unsatisfactory; for it is the kind rather than the amount of organic matter that renders this injurious. All recent advances in medicine point to the presence of organised organic matter, or possibly definite chemical bodies the products of changes evoked by organisms, as the potent factors in producing those diseases referrible to the use of polluted water. Hence, standards having reference to the quality rather than the quantity of organic matter present in waters are desirable; but no such satisfactory standards have been hitherto devised. There are, however, the three modes of detecting, or rather gauging, the quantity of organic matter present in a water already described; and these, by the aid of other data often available, enable the practitioner in public health to arrive at a satisfactory conclusion as to the potability or the probable noxious character of a water. These methods are, the organic combustion process of Dr. Frankland, the Wanklyn process, and the permanganate process respectively, and are commonly known by the names of those chemists; and the permanganate is often referred to as Dr. Tidy's process, he having improved upon the older permanganate processes previously used. The assessment of the values to be attached to each of the determinations of a water analysis, and to the whole determinations collectively, is a subject on which the greatest diversity of opinion has existed among chemists, and which still exists to some extent. It is chiefly over the determinations of organic matter, and the determinations, such as the amount of oxygen absorbed from permanganate, which serve as indices to the amount of organic matter, though not directly serving as measurers of this, that the battle of water-analysis has raged most furiously; but most, perhaps, of all as to relative values of the figures obtained by the Frankland combustion and the Wanklyn albuminoid ammonia processes. The writer of this article is of opinion that a water must be judged—so far as it can be judged by analysis alone—by the whole results of the analyses, and not by one constituent, be it organic nitrogen or albuminoid ammonia, alone. But he

deprecates, nevertheless, the attempt made by the late Mr. Wigner and by other members of the Society of Public Analysts ('Analyst,' 1881, vol. vi., p. 111) to attach a numerical value to the amount of each one of the important constituents, such as total solids, hardness, chlorine, ammonia, &c., and then to assess the impurity of a water by a summation of those numbers, e.g. saying that the impurity of a water is 20, 10, 17, &c., as the case may be. The values attaching to the determinations of the several constituents of a water will now be briefly discussed; but it will be well first to set out the opinions of some leading authorities as to the deductions to be drawn from analytical analyses of waters.

Dr. Frankland thus classifies waters according to their organic purity ('Water Analysis,' p. 86):—

Upland Surface Water

Class I. *Water of great organic purity*, containing a proportion of organic elements (organic carbon and organic nitrogen) not exceeding 0·2 part in 100,000 parts of water.

Class II. *Water of medium purity*, containing from 0·2 to 0·4 part of organic elements in 100,000.

Class III. *Water of doubtful purity*, containing from 0·4 to 0·6 part of organic elements in 100,000.

Class IV. *Impure water*, containing more than 0·6 part of organic elements in 100,000.

Water other than Upland Surface

Class I. *Water of great organic purity*, containing a proportion of organic elements not exceeding 0·1 part in 100,000.

Class II. *Water of medium purity*, containing from 0·1 to 0·2 part of organic elements in 100,000.

Class III. *Water of doubtful purity*, containing from 0·2 to 0·4 part of organic elements in 100,000.

Class IV. *Impure water*, containing upwards of 0·4 part of organic elements in 100,000.

Dr. Frankland thus further classifies waters (*ibid.*, p. 97):—

1. *Reasonably safe waters.*—Water, although it exhibits previous sewage or animal contamination, may be regarded as reasonably safe when it is derived either from deep wells (say 100 feet deep) or from deep-seated springs, provided that surface water be carefully excluded from the well or spring, and that the proportion of previous (sewage) contamination do not exceed 10,000 parts in 100,000 parts of water (i.e. the inorganic nitrogen does not exceed 0·968 part per 100,000, or 0·678 grain per gallon.—T.S.).

Suspicious, or doubtful water is (1) shallow-well, river, or flowing water which exhibits any proportion, however small, of previous sewage or animal contamination; and, 2nd, deep-well or spring water containing from 10,000 to 20,000 parts of previous (sewage) contamination in 100,000 parts of water (i.e. 0·968 to 1·92 part inorganic nitrogen per 100,000, or 0·678 to 1·344 grain per gallon).

Dangerous water is (1) shallow-well, river, or flowing water which exhibits more than 20,000 parts of previous animal contamination in 100,000; (2) shallow well, river, or flowing water containing less than 20,000 parts of previous (sewage) contamination in 100,000 parts, but which is known, from an actual inspection of the well, river, or stream, to receive sewage,

either discharged into it directly, or mingling with it as surface drainage; (3) as the risk attending the use of all previously contaminated water increases in direct proportion to the amount of such contamination, the water of deep wells or deep-seated springs exhibiting more than 20,000 parts of previous contamination in 100,000 must be regarded as dangerous. River or running water should only be placed in the second class provisionally, pending an inspection of the banks of the river and tributaries, which inspection will obviously transfer it either to the class of reasonably safe water if the previous contamination be derived exclusively from spring water, or to the class of dangerous water if any part of the previous contamination be traced to the direct admission of sewage or excrementitious matters.

Dr. Tidy thus formulates his own conclusion as to the respective merits of the various processes for the determination of organic matter in water ('Journal of Chemical Society,' vol. xxxv., 1879, p. 96):—

1. As regards the ammonia process, an absolute or nearly absolute freedom from albuminoid ammonia is for the most part an indication of organic purity. Nevertheless, many waters which are very impure give a trace only of albuminoid ammonia, whilst some which are very pure give large quantities of albuminoid ammonia. Its results, therefore, are marked by singular inconstancy.

2. That the ammonia process allows of no sufficiently large scale whereby the finer grades of purity or impurity can be recognised and classified. The errors arising from many causes—such as, amongst others, the ammonia present in the permanganate solution itself, the difference in time required by different organic bodies for their complete destruction, the chances of the organic nitrogen becoming oxidised, the constant multiplication of errors of observation resulting from collecting several distillates in which the ammonia is to be severally determined, and which errors are again doubled in order to convert results into parts per million—form an array of difficulties likely to lead to serious errors, seeing that the range (viz., from 0·05 to 0·1 part per million) between waters of extraordinary organic purity and dirty waters is comparatively small.

3. That, as regards the combustion process, the necessity for evaporating the water to dryness constitutes a difficulty, the chances being that some of the organic matter, and possibly that subtle form of organic matter specially active in producing disease—the very organic matter, in fact, the detection of which the sanitarian expects from the chemist—may be either mechanically carried off, or volatilised, or oxidised, or even destroyed under the peculiar conditions of the evaporation.

4. That, barring this objection, the estimation of the organic carbon in the water residue is trustworthy, repeated experiments with the same water yielding constant results.

5. That the estimation of the organic nitrogen is by no means so constant, the possibility of the nitrate not being completely reduced, especially when present in quantity; of impurities in the sulphurous acid solution; of occluded nitrogen in the metallic copper; and, lastly, the necessary error of experiment, constituting a series of difficulties which must somewhat impair the nitrogen determination.

6. Under such circumstances, the process can scarcely be considered to yield absolutely trustworthy evidence (unless the organic nitrogen be beyond a certain quantity) on which to found an opinion as to the probable source of the organic matter in the water.

7. As regards the oxygen process, he claims for it that it is conducted on

the original water and without the application of heat. Hence we avoid the evils both of gain and of loss arising from, and incident to, the evaporation of the water to dryness at high temperatures. Moreover, the analysis can be conducted with the smallest possible amount of handling, or of pouring the water from vessel to vessel.

8. That the process gives results of great constancy and of *extreme* delicacy. They admit, moreover, of a very wide scale in their classification.

9. That the oxygen process allows us to draw a sharp distinction between the putrescent or readily oxidisable organic matter, which is the more likely, to use Dr. Frankland's term, to be 'pernicious,' and the non-putrescent or less readily oxidisable matter, which is probably harmless so far as its action on the human body is concerned.

10. That the general inorganic constituents of the water have no action on potassic permanganate.

11. The inorganic constituents most likely to be present in a water that would interfere with the estimation of the organic matter by potassic permanganate are nitrites, metallic protoxides (especially ferrous salts), and sulphuretted hydrogen, all of which are certain to be detected in the course of a proper and complete water analysis, and corrections made accordingly.

12. That in the oxygen process the only modifying circumstances are those which would render the oxygen required by the water excessive, and that therefore, although we might be led to report unfavourably on a harmless water, the results obtained would never lead us to report favourably on a bad water.

13. That whilst he does not consider that the oxygen process can be employed with scientific precision as a direct quantitative test of the total organic impurity of a water, nevertheless the results afforded by it indicate with sufficient precision the comparative quantity present likely to be injurious to health.

14. That the results obtained by the oxygen process must at all times be controlled by the natural history, as well as by the general, chemical, and physical examination of the water.

15. That, so far as the three processes—viz. the combustion process, the ammonia process, and the oxygen process—are concerned, the oxygen and the combustion processes give closely concordant results, whilst the results yielded by the ammonia process are often at direct variance with both.

After a full consideration of the respective merits of the Forchammer, or oxygen, and the combustion processes, Dr. Frankland ('Water Analysis,' p. 57) gives the following scale of classification of drinking-waters, suggested by Dr. Tidy and himself:—

Upland Surface Water

Class I.—Water of great organic purity, absorbing from permanganate of potash not more than 0·1 part of oxygen per 100,000 parts of water, or 0·07 grain per gallon.

Class II.—Water of medium purity, absorbing from 0·1 to 0·3 part of oxygen per 100,000 parts of water, or 0·07 to 0·21 grain per gallon.

Class III.—Water of doubtful purity, absorbing from 0·3 to 0·4 part per 100,000, or 0·21 to 0·28 grain per gallon.

Class IV.—Impure water, absorbing more than 0·4 part per 100,000, or 0·28 grain per gallon.

Water other than Upland Surface

Class I.—Water of great organic purity, absorbing from permanganate of potash not more than 0·05 part of oxygen per 100,000 parts of water, or 0·035 grain per gallon.

Class II.—Water of medium purity, absorbing from 0·05 to 0·15 part of oxygen per 100,000, or 0·035 to 0·1 grain per gallon.

Class III.—Water of doubtful purity, absorbing from 0·15 to 0·2 part of oxygen per 100,000, or 0·1 to 0·15 grain per gallon.

Class IV.—Impure water, absorbing more than 0·2 part of oxygen per 100,000, or 0·15 grain per gallon.

Mr. Wanklyn's standards of organic purity are as follows ('Water Analysis,' p. 68):—

Class I.—Water of extraordinary organic purity, yielding from ·00 up to ·05 part of albuminoid ammonia per million. This class comprises the most carefully prepared distilled water and highly filtered waters, both *natural* (i.e. deep spring waters) and *artificial* (i.e. such water as has passed through a 'silicated carbon filter' in good working order). Occasionally a river-water in its unfiltered condition falls into this class. Water of this class cannot be objected to organically.

Class II. comprehends the general drinking-waters in this country. It gives from 0·05 to 0·10 part of albuminoid ammonia per million. Any water falling fairly into this class is safe organically.

Class III. comprehends the dirty waters, and is characterised by yielding more than 0·10 part of albuminoid ammonia per million.

The writer is of opinion that no water should be judged by the quantity of any one or two constituents which it may contain, but that the composition of a water as a whole should be taken into consideration in passing judgment upon its presumable safety when used as a drinking-water, and its admissibility as a source of domestic supply. To rely upon organic carbon, or albuminoid ammonia, or ammonia, or oxygen (from permanganate) consumed, may lead to the rejection of a good, or to the adoption of a bad water. It may, therefore, be advisable to offer some observations upon the various constituents of waters.

Gases.—Waters vary considerably in the proportions of their gaseous constituents. When freely exposed to the air, a good water which is not consuming oxygen by means of the organic matter, nitrites, or ferrous salts which it contains ought to contain about $1\frac{3}{4}$ cubic inches of oxygen per gallon; and, to be palatable, to contain a fair proportion of carbonic acid gas in solution, so as to be brisk and not vapid in flavour.

Odour.—There should be none; but the presence of a trace of sulphuretted hydrogen odour when freshly drawn from a deep source is not prohibitory of its use.

Taste.—This should, of course, be agreeable, and not distinctive of any special substance, subject to the qualification just given.

Turbidity.—There should be none; or, if any, this should be due to vegetable or mineral matters, and easily removable.

Colour.—There should be none; but a slight peaty colouration is no bar to the use of the water.

Keeping-Powers.—A good drinking-water, when kept in a bottle loosely plugged with sterilised cotton-wool, should not become putrid, nor deposit anything beyond an inconsiderable amount of chalky matter.

Total Solids.—The amount of solids in a good drinking-water is a very variable amount, and depends a good deal on the geological stratum of the district. Dr. E. Parkes was of opinion that a good potable water should not contain more than 35 grains per gallon of solids, or 50 per 100,000. As a matter of fact these may range from 4 per gallon, or 6 per 100,000, to 50 or 60 grains per gallon or 80 per 100,000; and no doubt even these last figures may exceptionally be exceeded. Some of the best artesian well-waters in London contain over 50 grains per gallon of solids, much of which is common salt; and the highly valued table-waters imported from the Continent contain nearly 100 grains per gallon of mineral constituents, or 140 per 100,000. It is, indeed, rather the quality than the quantity of mineral matter present which is to be regarded in judging of the suitability of a water for domestic use. As a rule, however, those waters which contain least mineral matter are deemed most suitable for domestic supplies, though there is high authority for thinking that a certain amount of chalk in a water is beneficial. In one respect this is an advantage, for such waters, being slightly alkaline, act but little on lead; whereas the soft waters containing little solid matter are often acid, and act freely upon leaden pipes and cisterns.

Loss on Ignition.—The loss which the dry solid matter obtained by evaporation of the water under examination undergoes when ignited is nowadays but little regarded. When coupled with the manner in which the solids behave during the burning process, this determination is, however, a valuable one. The blackening, the odour, and the character as regards colour and acidity of the fumes evolved should by no means be neglected, for in this way the experienced analyst will obtain valuable information. The actual amount of loss—correction being made for the substitution of the N_2O_5 radical of nitrates by the CO_2 radical of carbonates during ignition—is also an index of quality, provided chlorides and sulphates are not very abundant. When these are present, the loss is increased by the loss of water of hydration of these salts not expelled at the temperature at which the water residue was dried in the oven. In an undoubtedly good water the loss on ignition is small—1 or 2 grains perhaps per gallon—and the residue during ignition, though it may assume a shade of brown or grey, never really blackens or evolves the odour of burnt feathers.

Hardness.—The use of a water of more than 20 degrees of hardness (Clark's scale) is undesirable; and an ordinary good water ought not to have more than 15 degrees of hardness. The use of a water of 25 degrees of hardness is, however, permissible when no softer water is available. The permanent hardness of a good water should not exceed 5 degrees.

Nitrates.—The nitrogen as nitrates should, in no case, exceed 1 grain per gallon ($= 3{\cdot}86$ grains N_2O_5); $0{\cdot}7$ grain N ($= 2{\cdot}7$ grains N_2O_5) per gallon is a safer limit.

Nitrites.—These should be absent.

Chlorine.—If the chlorine exceeds 1·5 grain per gallon, its source should be inquired into; and if there be also much ammonia, and especially albuminoid ammonia, or organic carbon present, or if the water consumes much oxygen in the permanganate process, sewage contamination may be apprehended. The deep artesian well waters of the London basin contain much chlorine and ammonia, and are wholesome; but they yield little organic carbon and albuminoid ammonia, and they consume little oxygen (from permanganate).

Organic Matter.—The loss on ignition should not exceed 2 or 3 grains per gallon of water, and the fumes evolved during ignition should have no

animal odour. The evolution of ruddy acid vapours indicates excess of nitrates. Albuminoid ammonia should not exceed 0·01 grain per gallon (0·15 per million) except in the case of peaty waters, when the albuminoid ammonia is evolved slowly. Ammonia (so-called 'free' ammonia) ought not to exceed 0·002 grain per gallon, except in the case of an artesian well-water. If the oxygen consumed in the permanganate process exceeds 0·2 grain, or at most 0·25 grain per gallon, the purity of the water is open to grave suspicion. Organic carbon should not exceed 0·3 grain per gallon, nor organic nitrogen exceed 0·03 grain per gallon; and whenever the ratio of organic C to N is less than 5 to 1, the water is open to suspicion.

Only one or two of the determinations—organic carbon *plus* organic nitrogen, albuminoid ammonia, oxygen consumed—are usually employed in conjunction with the other analytical data in judging of the quality of a water-supply. Koch is of opinion that a normal water is one which contains less than 300 germs in each cubic centimetre. Plugge and Kroskauer would not permit more than 50 to 150 germs at the most, and the Swiss Society of Analytical Chemists fixed the latter figure as their maximum. A. Pfeiffer condemns a water when the germs reach 1000 per cubic centimetre (Ferd. Fischer, 'Zeitsch. f. Angew. Chemie,' 1889, No. 18). These conclusions are widely diverse, and no account is taken of the kinds of germ met with. It is obvious that until we have some means of distinguishing between innocent, and perhaps beneficent, germs and those which are disease-producing, the mere counting of germs is a valueless operation.

Injurious Metals.—The water should yield no colouration, or only the faintest tint of colour, on the addition of tincture of galls (absence of excess of iron), and it should not darken on the addition of a drop of sulphide of ammonium followed by a drop or two of strong hydrochloric acid (absence of lead and copper).

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THE INFLUENCE OF SOIL ON HEALTH

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THE INFLUENCE OF SOIL ON HEALTH

From the times of Herodotus and Hippocrates to the present day, evidence has been gradually accumulating as to the influence exerted by the nature of the soil on the prevalence of certain diseases, more particularly malaria, to which must now be added cholera, diarrhœa, typhoid or enteric fever, phthisis, and many others which will be treated of in detail later on.

By the term soil is understood such portion of the earth's crust as has been formed by the gradual disintegration through many ages of the rocks of which the globe is mainly constituted. The composition of the soil therefore varies considerably in different localities, but in comparing one with another it is well to bear in mind the many other factors, in addition to the composition and condition of the soil, which from time to time may come into play.

A subdivision into surface soil and subsoil is generally recognised, and is useful for practical purposes, seeing that the upper portion of the soil or 'mould' differs very materially from the subsoil in composition. The latter consists for the most part of inorganic materials, while the former may contain in addition large quantities of organic matter, both animal and vegetable in origin, the *rôle* of which is a most important one, since it is in great measure to these constituents, and the manner in which they are affected by varying degrees of moisture, temperature, and aëration, that the effect produced on the health of the community is due.

Above the rock which will be found at the lowermost portion of a section perpendicular to the surface of the earth, we find then the *subsoil*, which results from the breaking up of the rock under the influence of various agencies, such as the percolation of water containing various gases and other substances in solution, or from the irresistible onslaught of the roots of trees which, forcing their way gradually downwards, split it asunder. The subsoil is thus continually eating its way into the rock beneath, to compensate for which, influences are as continually at work causing an imperceptible removal of material from the surface of the soil. Above the subsoil again we find a layer penetrated in all directions by the rootlets of the vegetation on the surface, indicating a still further stage in the decay of the remains of the primitive rock. This layer forms the true *soil*; the subsoil being an intermediate band where the progress of decomposition has not advanced so far.

If there is so intimate a connection between the soil at the surface and the rock underneath, we can readily understand that soils should vary from one district to another according to the nature of the underlying rocks. Denudation of clays will produce clayey soil, sandstones sandy soil, or where these two kinds of rock occur together, they may give rise to sandy clay or loam. Hence, knowing what the underlying rock is, we may usually infer what must be the character of the overlying soil, or from the nature of the soil, we may form an opinion respecting the quality of the rock that lies below (Geikie). The soil of every locality, then, ought to be merely the decayed upper surface of the rocks underneath, mingled with the remains of animal and vegetable matter, were it not for the action of rain and other forces in removing material to a greater or less distance from its source, by which in some instances a good soil is laid down upon rocks which of themselves would only produce a poor one.

Since soils are formed more or less directly from the decomposition of rocks, it will be advisable to mention shortly the manner of origin of these rocks, and also their chemical composition.

The various rock-formations have been divided under two principal heads according to their mode of origin: the *igneous* and *sedimentary* rocks. The first class, which includes only a few of the rocks with which we are now acquainted, is believed to have been derived from the gradual cooling down of the outer surface of the molten mass of which the globe at first consisted, whence their name. Although the proportion of igneous rocks cropping up above the surface in Great Britain is so small (even in North Wales, where they are found to the greatest extent), still they are none the less of importance, seeing that to their decomposition the origin of the later rocks is due. Of the igneous rocks the most important is granite, which may exist in many different forms, and after this the trap rocks, including the greensands and basalt, which are looked upon by some as essentially the primary rocks from the considerable resemblance which they show in chemical composition to volcanic lava.

Granite of various kinds consists mainly of quartz, feldspar, and mica in various proportions, although any one of these three constituents may be absent, or replaced by some other substance. Thus a rock in which hornblende replaces mica is known as syenite, while, if both these substances are present, it is termed syenitic granite. Gneiss, again, contains the usual elements of granite, but the crystals of quartz and feldspar are broken and indistinct. The trap rocks consist mainly of feldspar and hornblende (or augite, which contains less silica than hornblende), and the general composition of the minerals composing the igneous rocks may be shown as follows:—

Analyses of Minerals (*Lloyd*)

—	Hornblende		Mica	Feldspar	
	Without Alumina	With Alumina	Potash	Potash Orthoclase	Soda Albite
Soda	—	3·14	4·10	—	11·47
Alumina	—	6·31	36·23	17·50	19·43
Manganese oxide	—	1·13	—	—	—
Calcium oxide (lime)	15·06	9·68	·50	1·25	·20
Magnesium oxide	23·92	3·62	·37	—	—
Potash	—	2·65	6·20	12·00	—
Ferrous oxide	2·41	21·72	—	—	—
Ferric oxide	—	6·62	1·34	1·75	—
Silica	54·71	42·27	44·60	66·75	69·00
Loss on ignition	3·33	·48	5·26	—	—
	99·43	97·62	98·60	98·25	100·10

Quartz is not mentioned in the table, as it consists of almost pure silica alone. Mica, hornblende, and feldspar, on the other hand, are of a much more complicated nature, the main difference between hornblende and feldspar being seen in the large amount of lime and magnesia present in the former, while in the latter there is much potash or soda, but practically no lime.

'Thus the igneous rocks consist mainly of four elements: quartz, feldspar, hornblende, and mica. From the decomposition of these rocks, and re-formation of the decomposed parts, the aqueous rocks have been formed.' The terms *aqueous* or *sedimentary* are therefore used, because it appears that these rocks must have resulted from the gradual solution and disintegration by rain of the older igneous rocks, the fine particles of which, held in suspension in the water of streams, lakes, and seas, have thus been carried to lower

levels and then again gradually deposited, the resulting deposits constantly increasing and forming accumulations of greater or less thickness, and becoming arranged in layers or strata from the separation of the particles of various size and shape. From this cause arise the differences in the mechanical and chemical composition of the various sedimentary rocks, which from the fact that they have either been formed by deposition in water in the manner described, or by precipitation of matter held in solution by the water, all resemble one another in forming more or less distinct layers. For this reason the term *stratified* has been applied to them; the relative time of their formation having given rise to the geological terms of primary, secondary, and tertiary, by which the three main groups are distinguished.

These principal divisions of stratified rocks include about eighteen distinct strata, on each of which a special name has been bestowed. The more important of these are:—

The old red sandstone.
The new red sandstone (sandstone and marl).
The greensand formation (sandstone, clay, and sand).
The claystone formations: Lias. Oxford. Kimmeridge. Wealden. London.
The limestone formations: Mountain limestone. Magnesian „ Oolitic „ (Bath stone).
The chalk formation.

From these various rocks the overlying soil has been for the most part formed partly by the process of 'weathering,' but also in large part by the action of both animal and vegetable life. As the plants on the surface die, their remains gradually rot, as do those of others that succeed them, so that by the gradual accumulation of the *débris* of successive generations, the surface soil becomes more or less black, and is found to consist largely of organic matter of vegetable origin. The animal world, too, is not unrepresented, since not only those creatures which naturally live in the earth in such enormous numbers, such as various insects and earth-worms, contribute their quota after death to the constituents of the soil, but larger animals as well which fell when dead upon the surface of the earth, or were purposely buried beneath it, and thus in either case become in time incorporated with it. The excrement of the animal world also is constantly being added to the soil, and thus also gradually comes to form an integral part of it. In this way from both plants and animals there is furnished to the soil that organic matter on which its fertility so much depends, a fact the results of which have long been known to agriculturists, who recognise the greater fertility of the upper stratum of the soil, which differs in this respect from that immediately below it.

It might be supposed that the gradual formation of a covering of soil and subsoil, particularly where there is in addition an overlying abundant vegetable growth, would in course of time, by the protection it affords, come to prevent any further decomposition and disintegration of the rock beneath; although this may be so to a certain extent, the process never ceases altogether. If it were so, plants after a time would cease to grow from want of the necessary inorganic constituents of the soil, and either the tract of country would become a waste, or at most only the humbler forms of vegetable life would persist. The continued growth of similar kinds of plants shows, however, that

they are able in some way or other to continue obtaining their necessary nutriment from the soil, this in turn depending on the decomposition of fresh portions of the underlying rock. This is in fact due to the actual growth and decay of the vegetation itself, since rain falling on the surface and gradually percolating through the soil absorbs certain vegetable acids, the true nature of which is still somewhat obscure, but which, when present to a considerable extent, bestow on it a power of gradually eating into the substance of rocks over which it flows. In the case of water issuing from extensive beds of peat, for instance, the amount of these organic acids in solution would be sufficient to produce an appreciable effect on the stones or rocks with which it came in contact, limestone rock being particularly liable to corrosion from such a cause.

In addition, rain, as it percolates through the soil, carries down with it a certain amount of oxygen and carbonic acid which it has dissolved from the atmosphere, while more carbonic acid, which is always present to a certain extent in the soil itself, is dissolved by the water in its downward passage. Constituents of the underlying rock are thus dissolved which would not be acted upon by water alone. Limestone is particularly liable to be affected in this manner, for though only a part of the rock may become dissolved, the remainder will tend as the rock becomes exposed to become split up into fragments by the subsequent action of frost. Carbonic acid also acts on iron, which it dissolves in considerable quantity, and it causes the decomposition of feldspar by combining with the potash and soda present in this mineral. Oxygen also acts on all rocks which, like hornblende, contain salts of iron, the green ferrous compounds being converted into red ferric oxide, and thus disintegration is also brought about.

The conjoined action of water and gases upon the rocks, which is termed 'weathering,' is of necessity exceedingly slow, but when extended over periods measured by centuries, it will be understood that enormous results may be produced by the continuous disintegration which goes on. Water, however, does not only act by virtue of the substances dissolved in it, but has a distinct mechanical action as well. Thus we find that not only the primary rocks, but those of a sedimentary nature also, are frequently more or less fissured, and if the crevices exist in certain directions they will become more or less filled with water after a time. If now a frost ensues, the expansion of the water which occurs, as it becomes transformed into ice, will exert an immense force which will not only tend to increase the extent of the fissure, but may even split off, not only fragments, but also considerable portions of the rock. Naturally the results of this action will be more obvious in temperate climes, where there will be alternate frost and moderate heat in winter and summer respectively, while in tropical countries, where frost is unknown, or in the arctic regions, where it is perennial, the results of such will be comparatively slight.

Flowing water and the movements of glaciers have also both exerted considerable influence in this direction; fragments of rock becoming broken off, and these continually rolling against one another are gradually broken up into smaller pieces, the surface of the land thus becoming gradually transformed. Much of the material thus broken up by the influence of water or ice may be transported for a considerable distance and then again deposited, the soil thus formed being termed *alluvial* when deposited from water, and *drift* when the result of glacial action.

Of the former class, the soils formed at the mouth of large rivers such as the Nile are examples, while in England typical soils of this character are found in the Fens of Cambridgeshire and Lincolnshire. On the other hand, drift action has considerably modified the soil in many parts of Great Britain,

and for the most part improved it, since 'where slopes descend and are covered more or less with old ice-drifts and moraine matter, the soil is deep and the ground is fertile. The re-arrangement of the ice-borne *débris* has served to cover large tracts of country with a happy mixture of materials, such as clay mixed with pebbles, sand, and lime.'

There is, moreover, a constant transposition of soil going on, not only from the washing away of the surface by rain or its removal by wind in the form of dust, these being most noticeable where slopes are steepest or when the weather is driest respectively, but from the substitution of new surface-soil due to the upraising of a certain amount of material from deeper layers. This is in part brought about by the labours of rabbits, moles, and other animals in throwing out soil from their burrows, while in tropical countries the termite or 'white ant' carries an enormous amount of fine earth up into the open air, forming hills in this manner which may rise to a height of as much as sixty feet. The most enormous amount of work in this direction, however, is performed, slowly it is true, but none the less surely, by earthworms. They disintegrate the soil, riddle it with burrows, and so admit air to its deeper recesses, and in their castings bring up to the surface an almost incredible amount of fine soil in the course of a year. Darwin has shown that in some places the quantity of earth raised to the surface may reach to as much as ten tons to an acre. Thus inequalities tend to become levelled, while stones and other material of an inorganic or organic nature are gradually buried. The organic and excremental matter thus buried becomes to a large extent the prey of various saprophytic fungi, which abound in the soil and find in it a pabulum well suited to their needs. In earth they flourish to a greater extent even than in the atmosphere, as might be expected, seeing that the amount of food-material is so abundant, while for the same reason they will be more abundant near the surface than at some distance beneath it.

BACTERIA AND THEIR INFLUENCE ON SOIL [1]

According to Flügge, enormous numbers of bacteria have always been found in the soil by various observers. Infusions made from manured field and garden earth, even though diluted one hundred times, still contain thousands of bacteria in every drop, and the ordinary soil of streets and courts also shows the presence of large numbers. Bacilli are present in much the largest numbers, but in the most superficial layers and in moist ground there are also numerous forms of micrococci.

Through the agency of these bacteria, organic substances which reach the soil, and which are for the most part retained in the superficial layers, undergo gradual change, which for the most part is in the direction of oxidation and occasionally in that of reduction or putrefaction. That such change is brought about by the vital activity of micro-organisms is evident from the fact that if the soil be sterilised, as by the action of heat, no such metamorphosis takes place in the chemical nature of its constituents. One such property of great importance possessed by soil in virtue of the presence of some one or more of these lowly organisms is that of nitrification, as was shown long ago by Frankland, who found that the effluent from sandy soil over which London sewage had been passed was clear, and contained the representatives of the organic matter of the sewage in the form of nitrates and nitrites. Experimenting in a similar manner, Fodor found that when a fluid containing a considerable quantity of ammonia—a large excess of organic material with

[1] Bacteria will be more fully dealt with in a paper by Dr. Klein.

a trace only of nitrites and nitrates—was poured over a certain amount of earth, consisting of a mixture of humus and sand, he recovered in the filtrate the faintest indication of ammonia only, about one-fortieth of the organic matter, and nearly fifty times the amount of nitrates and nitrites. He found, however, in addition, that if the sewage were poured too continuously on to the soil, the constituents accumulated in great part in the superficial layers, and failed to undergo a similar conversion.

Schlösing and Muntz showed in 1878 that the process of nitrification was dependent upon the presence of certain micro-organisms—that it was in fact a fermentation change, but they did not succeed in isolating any one form specially concerned. This has apparently been done quite recently by Percy and Grace Frankland, who, by using a dilution method, have separated what they term a bacillo-coccus, which is capable of inducing nitrification in ammoniacal solutions inoculated with it. Warrington, however, in a recent paper read before the Chemical Society, states that the nitrification performed by soil appears to be the work of two organisms, one of which oxidises ammonia to nitrite, while the other oxidises nitrite to nitrate. The first organism is easily separated from the second by successive cultivations in solution of ammonium carbonate. The second is (probably) separated as easily from the first by successive cultivations in solution of potassium nitrite containing monosodium carbonate.

It has been shown conclusively by Flügge, Koch, and others, that the various micro-organisms found in soil are much more numerous in the superficial layers than at a greater depth. Indeed, at any distance from the surface they are practically absent unless the soil has been deeply trenched, as in preliminary drainage operations, or unless liquid filth from sewers and cesspools has been carried off beneath the soil. This is accounted for by the fact that the soil is capable of retaining even such small bodies as bacteria, when filtration of water or sewage is slowly carried on through its interstices, although if the filtration be more rapidly effected such bodies will be carried to a greater depth. 'Numerous filtration experiments, on a large and small scale, have shown most distinctly that a layer of earth, half to one metre in thickness, is an excellent filter for bacteria, and hence the purification of fluids from bacteria must be still more complete in cultivated and especially in clay soil, and where the fluid moves with extreme slowness. Further, it has been repeatedly shown that wells which were protected against contamination with bacteria from the surface and from the sides of the well furnish a water almost entirely free from bacteria; that further, wells of water containing bacteria become the purer the more water is pumped out, and the more ground-water comes in from the deeper layers of the soil.'

That soil is capable of thus acting as a microbic filter can be shown by the following experiment. A flask A (fig. 85), half filled with some nutrient solution such as thin gelatine solution or peptone broth, is closed with a tightly-fitting cork, through which passes a glass tube B of fairly wide calibre, and somewhat constricted towards its lower end, which reaches down beneath the surface of the solution in the flask. Another tube C simply opens into the interior just below the cork, in such a manner that its external orifice is at right angles to the other tube B. C is now plugged with cotton-wool, and B is filled with dry powdered earth, which is packed fairly tightly, and the whole apparatus is then sterilised by heat. If now decomposing urine be poured into the upper end of B, it will slowly filter through into the flask, as will be seen from the heightened level of the contained fluid, but no decomposition will be found to occur in the gelatine solution since the bacteria will be retained in B. To show now that more rapid filtration

will carry them through into A, air is blown through the tube C, so as to drive the nutrient solution in A into B, say as high as D. On stopping the injection of air, the fluid will again rapidly rise in A, and putrefaction will shortly set in.

That the oxidation of organic substances in soil, as evidenced by the conversion of organic carbon into carbon dioxide and of nitrogen into nitric acid, is effected by the vital activity of micro-organisms is indicated by the following observations of Fodor :—

1. It is checked or stopped altogether by aspirating chlorine through the soil.

2. It is favoured by a moderately high temperature thus :—

After the soil has been kept at 18° C. for three days, amount of CO_2 in 1,000 volumes of air aspirated through soil	= 1·05
After being warmed to 60°–65° C.	= 2·30
" " 65°–95° C.	= 2·40
" " 95°–105° C.	= 1·00
" " 105°–115° C.	= 0·58
" " 115°–125° C.	= 0·15

So that the amount of carbon dioxide increases when the soil is heated to from 65°–75° C., remains stationary afterwards until the temperature reaches 95°C., then decreases quickly and markedly. It does not disappear wholly even when 137° C. is reached.

3. Schlösing and Muntz, in the course of their investigations on the influence of organisms in the process of nitrification in soil, found that the rapidity of the changes going on was considerably diminished when chloroform vapour was forced through the soil; proof of this fact being seen in a decrease of nitrates and nitrites in the effluent accompanied by a correspondingly large increase in the ammonia.

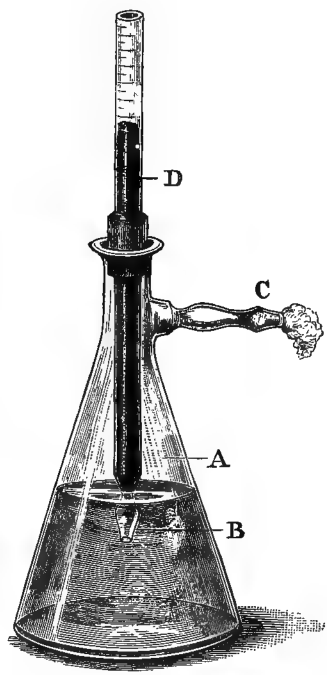


Fig. 85.

4. Nitrification, like other processes of a similar nature in the soil, is much less active than usual or may cease altogether when the soil has been thoroughly heated. Similarly Falk found that thymol, naphthylamine, nicotine, and other substances passed undecomposed through soil which had been exposed to considerable heat, while they wholly disappeared when added to soil which had not been heated.

5. Different forms of bacteria, especially bacilli, occur in almost all samples of earth. As the result of experiment it would appear that oxidation is due to the vital activity of micro-bacteria, while desmo-bacteria play a similar part in putrefaction, since they are able to thrive in the absence of air. Moreover, the bacteria concerned in nitrification are killed by exposure to a temperature of between 90° and 100° C., which suffices to kill micro-bacteria, but not the desmo-bacteria. Thus the fact that the formation of carbonic acid in soil is greatly reduced at 100° C., though not wholly stopped by a considerably

higher temperature, may be explained by supposing that at the former point the micro-bacteria, the chief producers of CO_2, are killed, while the desmo-bacteria, being capable of resisting even a higher temperature, survive and ultimately regain their activity.

The temperature of the soil, and the amount of moisture contained in it, are both important factors in determining the extent of changes going on as the result of the presence of micro-organisms. Thus it has already been seen that the amount of CO_2 produced in soil containing abundance of organic substances increases up to a temperature of about 60° C., while it is almost entirely arrested at a temperature of 100° C. or more. The amount of moisture most favourable to the production of CO_2 is reached when water is present to the extent of about 4 per cent., although the surface may be entirely covered with water, as Schlösing showed in his experiments on nitrification, without such changes becoming entirely arrested. Should the soil, however, be perfectly dry, decomposition does not take place.

Ventilation of the soil is another important factor. Thus Fleck buried rabbits in gravel, sand, and clay respectively, and found that decomposition proceeded more rapidly in sand and gravel, which allowed freer access of air, than in the more impermeable clay. Fodor states that if air be drawn through a tube charged with earth rich in organic matter, the carbon dioxide obtained increases in the same ratio as the velocity with which the air is drawn through the tube, while Soyka also found that the nitrifying power of soil increased when air was passed constantly through it. This effect, however, is not due to an increased supply of oxygen, since Schlösing, on aspirating soil with air containing different proportions of this gas, found that when more oxygen was supplied the production of carbon dioxide actually diminished, while on the other hand a considerable amount of carbon dioxide was produced when the aspirated air contained oxygen to the extent of only 1 per cent. The suggestion has been made that aspiration may act in the manner described, by removing products inimical to the organisms, in the sense that alcohol is inimical to the life processes of the yeast-fungus, that substances resulting from putrefaction, such as phenol, indol, and skatol, restrain the growth of putrefactive organisms, or that the products of digestion retard the further action of digestive ferments.

The *kind* of decomposition that goes on in a given soil varies according as air reaches the contained organic substances in small or large amount. It varies, in fact, with ventilation of the soil and therefore with its permeability to air, so that every natural phenomenon which alters the ventilation of the soil will also modify the processes going on in it, sometimes favouring oxidation, at other times putrefaction. Thus rising ground-water, by stopping up the pores of the soil, will conduce to putrefaction, as will also freezing of the upper layer of the soil, which destroys its permeability and thus favours putrefaction in the deeper and warmer portions. Supersaturation with organic substances has a similar effect, and hence the soil of cities is prone to undergo putrefaction rather than oxidation, both by reason of its greater degree of pollution and of the obstruction offered by pavements and buildings to due ventilation. That want of air is among the conditions for putrefaction is indicated by an experiment of Frankland's in which, when an extra amount of sewage was allowed to pass on to a certain field used for irrigation purposes, the effluent, which before had contained considerable amounts of nitrates and nitrites, now showed in their place undecomposed organic matter, ammonia, and certain faintly-smelling gases.

'The question whether among the bacteria which are found in the soil some may not be hurtful to mankind is of great interest and importance.

If disease-causing organisms find a nidus in the soil, may they not multiply or at least continue to live, and then prove a danger to health? There can be no doubt that pathogenic organisms do exist in the soil, but their power for harm would seem to be practically very small indeed; and to regard the soil as dangerous because some pathogenic organisms may lurk in it would be as rational as it would be to eschew vegetable food because of the occasional dangers of hemlock, aconite, or the deadly nightshade. It seems to be a fact that the great doctrine of the "survival of the fittest" holds good for microbes in the soil, as for all other organised bodies everywhere; and that organisms which flourish in the human body, languish and cease to multiply in the soil, where the conditions are unsuited for their multiplication or even for their survival. They get overgrown by saprophytic microbes, and even if they do not die, the risk of their finding their way into the ground water is practically nil, for we have seen that humus is the best of filters.' (Vivian Poore.)

Although doubtless the great majority of bacterial forms inhabiting the upper layers of the soil are simple saprophytes, organisms capable of inducing certain specific diseases are not unfrequently encountered. Among these may be mentioned the bacillus of tetanus (Nicolaier and Rosenbach), of anthrax (Frank), of malignant œdema (Koch and Gaffky), and of typhoid fever (Eberth and Gaffky). The bacillus of malaria described by Klebs and Tommasi-Crudeli should, perhaps, be included, although its pathogenic significance is not now generally accepted. In like manner, the microbe which Professor Domingos Freire, of Brazil, discovered in a burial-ground near Rio Janeiro, and which he believed to be the cause of yellow fever, is now stated on independent evidence to have no relation to that disease. Sherrington has isolated a pneumococcus from laboratory dust which is fatal to mice when inoculated subcutaneously, but whether it has any pathogenic importance in relation to human beings is at present unknown.[1]

Cholera bacilli have not hitherto been found in the soil, but Fränkel has shown experimentally that they can grow and multiply there at various depths. At a distance of about four feet from the surface their development was constant and progressive throughout the year. Diarrhœa, again, is a disease as to which, as the result of Ballard's researches, there is every reason to suspect that a definite micro-organism is necessary for its appearance, and, moreover, that such microbe has its normal habitat in the soil, although it has not as yet been isolated.

GROUND AIR

All soils contain a certain amount of air, the actual percentage depending on the looseness or otherwise with which the constituent particles are packed together. Many rocks, particularly the softer varieties, also contain air, only the very densest forms being practically free from it.

This air, which may exist in loose sands to the extent of about 50 per cent., or even more, consists in great part of carbon dioxide, while oxygen is usually present in smaller quantity than in atmospheric air. This was first pointed out by Boussingault and Lévy, who in 1852 analysed air which

[1] This was a bacillus found in the dust of an upper room in the Hygienic Institute, Kloster Strasse, Berlin, in March 1887. White mice inoculated with a fraction of a drop of the pure cultures died invariably, generally in about forty-eight hours. Rats inoculated with it generally, but not always, succumbed. Of ten guinea-pigs inoculated, one only died. The bacillus in many respects resembled Friedländer's pneumococcus, a point of distinction between them was, however, the more perfect anærobiosis of the pneumococcus. Spores were not detected.

they had aspirated from the soil at a distance of $1\frac{1}{2}$ feet from the surface, with the result that its composition was found to be—

Oxygen	10·35	per cent. of volume
Carbon dioxide	9·74	,, ,,
Nitrogen	79·91	,, ,,

Pettenkofer, next investigating the subject, confirmed the presence in the ground air of an amount of carbon dioxide in excess of that in atmospheric air, the amount increasing with the depth from which the air was drawn, and being influenced, moreover, by the season of the year—the greatest quantity at a given depth being found in autumn, and the least in spring. He stated his opinion that this CO_2 was due to the decomposition of organic substances under the influence of atmospheric air, which had found an entrance to the soil, and considered that the CO_2 of well-waters, and possibly that contained in the atmosphere, were in part derived from it.

Fleck, in Dresden, and Fodor, in Buda-Pesth, independently arrived at somewhat similar conclusions, and the former observer suggested that the amount of carbon dioxide might afford an approximate means of estimating the degree of pollution of the soil. This hypothesis, however, is contraverted by Fodor and Röller, who found that although the CO_2 was doubtless produced by the decomposition of organic substances, it did not afford so much an index of the pollution as of the permeability of the soil; a very polluted soil, if at the same time very permeable, containing even a smaller amount of CO_2 than a soil less polluted if also less permeable. Lewis and Cunningham found that the CO_2 in the ground air in the soil of a field near Calcutta which they examined, increased with the rainfall and decreased with dry weather, the amount also being greatest in the lower strata examined. In point of fact, it appears certain that the ground air consists for the most part of atmospheric air, which has penetrated into the pores of the earth, some of the oxygen of such air having become converted into carbon dioxide. Boussingault and Lévy, however, found that a certain specimen of ground air contained only 20·09 volumes per cent. of carbon dioxide + oxygen, and they supposed, therefore, that a small part of the oxygen had united with hydrogen obtained from organic substances in the soil to form water.

The oxygen of the air, then, on passing into the soil, enters into chemical combination with carbon derived from various animal and vegetable sources, and thus becomes replaced in some measure by an equal volume of CO_2. There must, however, be other influences also at work, since this statement is not invariably borne out, the percentage amount of oxygen and CO_2 together in the ground air being sometimes slightly higher and sometimes lower than in the atmosphere, a possible explanation of which may be found in the union of a certain portion of the oxygen with hydrogen to form water, and with nitrogenous organic bodies to form nitrates. On the other hand, the CO_2 which is formed may unite to some extent with the water in the soil, and also with alkalies, such as ammonia, and the basic earthy salts to form bicarbonates.

The suggestion has been made that the soil may, perhaps, absorb and condense gases after the manner of spongy platinum, and Röller cites some experiments which would appear to support this view, as on driving air through garden soil he found rather less CO_2 in the issuing than in the ingoing soil, whereas with dry sand the air passed through unchanged. Fodor explains this by inferring that although air passed through moist and polluted soil which had first been heated and then cooled does lose some of its CO_2, the loss is due to the water in the soil, which, losing its CO_2 when heated, takes it up again from the air passed through the soil.

The carbon dioxide in the ground air may be *greater* in amount than would correspond to the oxygen absorbed from the atmosphere. In such a case the excess of CO_2 is due to the vital action of putrefactive organisms, which may not only use the oxygen of the atmosphere, but also are capable of abstracting the oxygen of organic substances and also that of the nitrates in the soil. Thus, if a flask containing water with organic substances in solution, such as Cohn's fluid, after a short exposure to the air, be hermetically sealed up at the neck and then set aside for some days in a warm place, it will be found that if, after such a lapse of time, the gases in the flask be collected, their volume may be from 35 to 40 per cent. above the volume of the air in the flask before it was sealed up, the contained gases consisting of carbon dioxide and nitrogen in about equal parts, while oxygen will be conspicuous by its absence. In this connection it may be noted that, as stated above, even inorganic substances are reduced in the process of putrefaction, nitrates, according to Pasteur and Cohn, becoming converted into nitrites, and even into ammonia. Thus Schlösing, on drawing air containing different amounts of oxygen through earth containing putrefactive organisms, invariably found that carbonic acid was formed, while the amount of nitric acid in the soil was decreased.

Here we find an explanation of the fact that an increased amount of gas is found in the lower layers of the earth, particularly in autumn, when these layers are warmest, and when, therefore, the vitality of organisms concerned in decomposition processes would be most favoured. This was particularly noticed by Nicholas, who found an increase of gas in the air of his artificial earth in summer, and a decrease in winter; the volume of oxygen + carbon dioxide in this earth at a depth of fourteen inches having been in one series of experiments as follows:—

On June 21	26·2 per cent.
On July 26	26·7 "
On October 16	21·6 "
On November 10	19·7 "

Not only, then, does oxidation take place in the soil, but putrefaction also, as is seen from the fact that a relative increase in the amount of oxygen and carbon dioxide may temporarily occur. The more polluted the soil, and the more impermeable to air—whether originally so, as when it is largely composed of clay, or whether rendered so artificially by the pores of the upper layers becoming sealed up by rain—the more will putrefaction go on; whereas under opposite conditions oxidation alone will take place, putrefactive changes being wholly in abeyance. The presence of ammonia in the ground air indicates that putrefaction is going on in it, and since usually about four times as much ammonia can be obtained from the soil at a depth of four metres as at about a quarter of that depth, it would appear that putrefaction occurs more especially in the deeper layers, where there is practically no free oxygen, but where anærobic bacteria are known to thrive. There is, therefore, a greater tendency to putrefactive changes in the soil near the ground water than in the more superficial layers. (Fodor.)

The nitrogenous organic substances in the soil become in course of time converted into nitrates, which are washed into the deeper layers by the rain, becoming there reduced under the influence of bacteria into ammonia. This unites with carbonic acid there present, and may again pass up to the superficial layers, in solution in rising ground water, where it is seized upon by plants. For this reason it will be seen that, although ammonia may be found in the soil, an estimation of the actual amount present cannot be taken as an index of the activity of putrefactive changes which are going on.

The *nitrogen* present in soil is equal to that which would normally be present in the amount of atmospheric air which had penetrated the earth. There has, however, been considerable discussion as to whether any of it becomes absorbed or not, Deherain maintaining that a portion of it does thus disappear, while, on the other hand, Boussingault, Schlösing, and others state that it is impossible to find evidence of such absorption. Occasionally *sulphuretted hydrogen* is found in ground air, particularly if the soil be moist; it appears to be derived from the sulphates present in the hard water with which the soil is charged. *Marsh gas* or *carburetted hydrogen* also may occur as a result of the decomposition of certain organic substances; it may be obtained from putrid mud, and, as in the case of carbonic acid and ammonia, is found in greater amounts in the deeper layers. This increase of it at the greater depths is mainly due to greater difficulty of ventilation; indeed this factor may be even more important than the pollution of the soil, as an instance of which may be quoted Fodor's observation that at one place he found much more carbonic acid at four metres than at a depth of two metres only, although the organic carbon and organic nitrogen were in greater amount at the former point. As a rule, however, the relative amounts of carbon dioxide in samples of ground air taken from soils which have practically the same degree of permeability indicate the relative extent of impurity of these soils; when, however, the permeability varies, the rule does not, of course, apply.

The actual amount of *carbon dioxide* in soils varies, according to Boussingault's experiments, from 2·4 per 1,000 volumes to 9·74 in soils which have been recently manured. In alluvial ground Nichols found from 1·49 to 2·26 volumes per 1,000 in air, drawn from a depth of from $3\frac{3}{4}$ to $5\frac{1}{2}$ feet. Fodor gives as the results of thirteen observations at a depth of one metre, from 8·99 to 10·39, and at a depth of four metres (from eleven observations) from 26·31 to 54·45 CO_2, while Pettenkofer and Fleck have found it rise as high as 80 per 1,000 volumes in gravelly soils at depths of from five to thirteen feet.

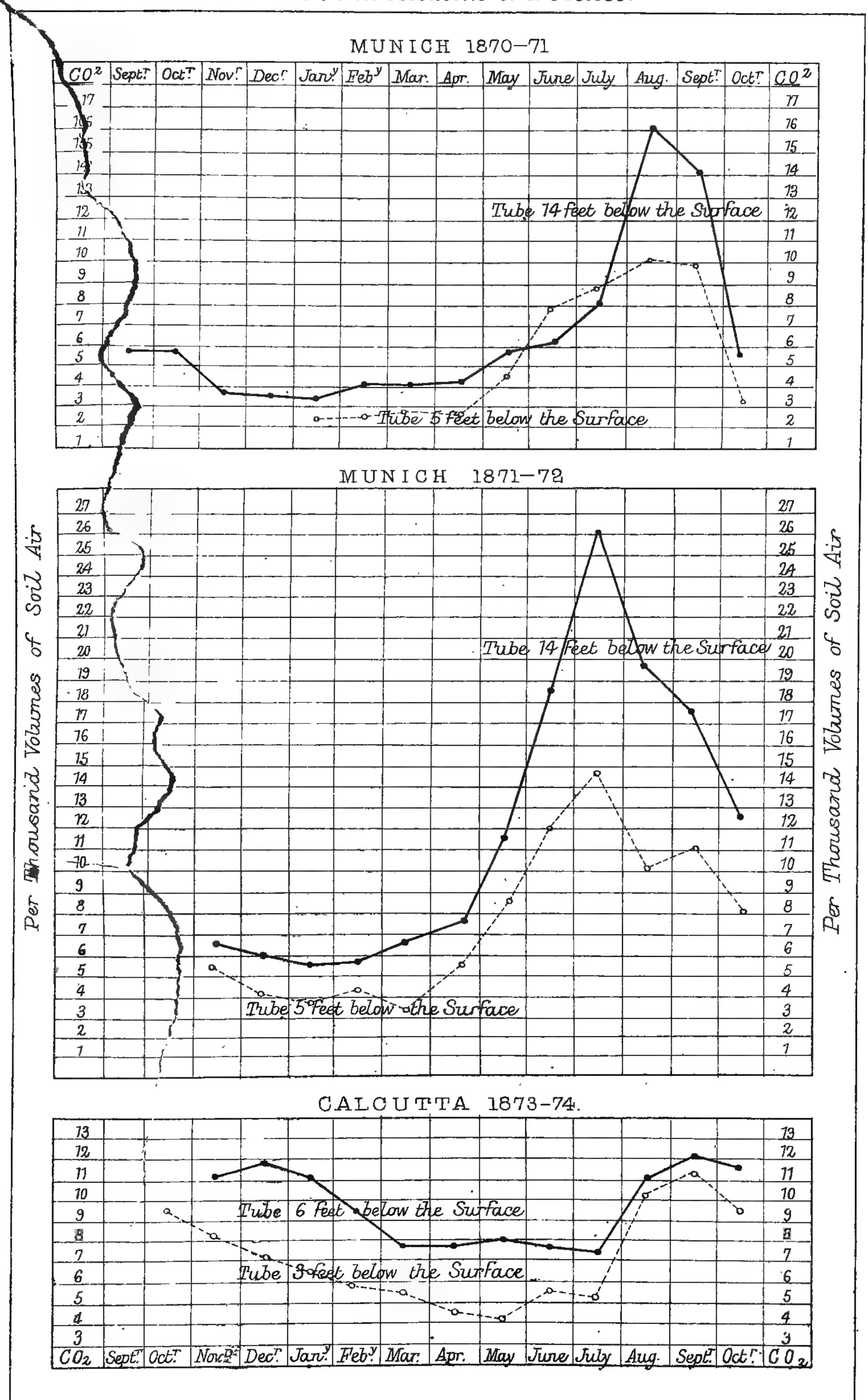
Annual and Seasonal Variations of CO_2 in Ground Air

It might reasonably be expected that in spring more CO_2 might be found for a short time in the superficial layers than in those lower down, owing to the fact that these upper layers become somewhat suddenly warmed. As a matter of fact, both Pettenkofer and Fodor have found that such is the case, the ground air in spring having for a longer or shorter period more CO_2 at a depth of one metre than the air obtained from a depth of two metres. In autumn, on the contrary, the CO_2 in the superficial layers sinks rapidly, and curves representing the respective amounts in superficial and deep layers become most widely separated.

By taking the average of a large number of observations, it appears that the amount of CO_2 in the soil rises in a uniform manner till the height of summer, and then sinks as the temperature subsides, and with the exception mentioned above, the variations at different depths show a certain degree of parallelism. (Plate II.) Owing, however, to the alternation of warming and cooling of the soil, the CO_2 maxima and minima do not occur quite simultaneously in all the layers although the greater amount is always found at the greater depth, as is shown in the following table compiled by Fodor at Buda-Pesth, as the average of a large number of observations extending over a period of three years.

The variations in the amount of CO_2 in the soil in different years and at different seasons depends on the amount of decomposition which is going on; this in turn undergoing fluctuations according to the amount of the rainfall

The Soil in its Relation to Disease.



Amount of Carbonic Acid at various depths in the Soil of Munich & Calcutta
(Lewis & Cunningham)

West, Newman lith.

and the prevailing temperature, the effect of the latter being very marked. Of course this concurrence is most marked in the superficial layers in which the variation is largest, and in which the soil is most polluted, and in which consequently the increase of warmth can effect the largest relative CO_2 production. In the deeper layers the CO_2, as also the temperature, usually reaches its maximum amount about a week later than in the superficial layers.

—	Amounts of CO_2 in the ground air as the mean of observations for three years			—	Amounts of CO_2 in the ground air as the mean of observations for three years		
	1 metre	2 metres	4 metres		1 metre	2 metres	4 metres
January .	6·5	12·6	25·0	July . .	15·8	22·8	35·9
February .	6·8	12·2	24·8	August .	12·8	20·7	32·6
March. .	7·0	11·8	24·7	September .	10·9	19·3	31·4
April . .	9·9	14·9	25·2	October .	9·8	15·0	29·4
May . .	11·5	16·1	27·2	November .	8·4	13·8	26·5
June . .	14·5	21·5	29·2	December .	8·1	12·6	25·8

Rainfall has also a marked effect upon the amount of CO_2 in the soil, an increase of rainfall being quickly attended by an increase of CO_2, while in dry weather the amount of CO_2 becomes reduced. Such an increase after rain is due to the blocking up of the pores of the superficial layers and a consequent accumulation of CO_2 in the deeper portions of the soil, and is almost immediately followed by a fall, the CO_2 being absorbed by the wetted soil. This general coincidence between a period of rainfall and a period of elevation in amount of carbonic acid is, however, much closer and more marked in reference to the carbonic acid in the upper than to that in the lower layers of soil, for, as Lewis and Cunningham found in the course of their investigations at Calcutta, the amount of carbonic acid in the latter continues high long after the cessation of the rains, and shows no immediate rise corresponding with their commencement in the following season.

Daily variations also occur to a certain extent, but they do not follow any very definite rule. They depend not so much on variations in decomposition processes as on wind, rain, and changes of atmospheric pressure. *Wind*, according to Pettenkofer and Fodor, sucks out the air from the soil, and so reduces the carbonic acid in it; the latter observer having found a decided decrease in its amount on 77 out of 111 very windy days. Under certain conditions, however, an opposite result may become apparent from the action of the wind forcing air into strata opposed to its path. Lewis and Cunningham found, however, that the velocity of the wind did not appear to exert any very distinct influence on the amount of carbonic acid in the soil as a rule, although, after an extreme and continued elevation of the wind during a couple of months, they found a sudden depression in the amount of carbonic acid in the upper layer of the soil in one locality, while there was no corresponding depression in the upper layer of the soil of a second station which happened to be much more shaded than the first. After a long continuance of still weather, they also noted a marked elevation in amount of carbonic acid at both places, probably due to the diminished ventilation of the soil which preceded it.

Changes in *atmospheric pressure* do not exert any very great influence on the amount of carbonic acid, although it would appear that on days on which the barometric pressure is very much below that on preceding days, the mean amount of carbonic acid in the soil at a depth of about three feet from the surface will be found to have risen, the probable explanation being that owing to the ground air escaping on the days of *low pressure* the ground air

from the deeper layers, which is more heavily charged with CO_2, rises into the more superficial layers. With an *increase* of atmospheric pressure, on the other hand, the carbonic acid shows no marked tendency either to an increase or decrease in amount.

Currents of Ground Air

From what has already been stated with regard to the fluctuations in the amount of carbon dioxide in the soil, it will be evident that the subterranean atmosphere which exists in the soil is in continual movement. This is mainly due to variations in the temperature of the earth and of the atmosphere which do not usually occur simultaneously, the variations of earth temperature for the most part following on similar variations in the temperature of the air, it being extremely rare for both earth and air to show the same temperature, at any rate for more than a very short time (Plate III.). Either the soil or the air will be the colder or the warmer, and consequently the ground air is continually moving, either passing from the deeper to the more superficial portions of the soil, or *vice versâ*. Naturally the greatest range of movement will occur when the soil and air are most different in temperature. In autumn and winter the soil is the warmer, and therefore the air present in it escapes into the atmosphere, the colder atmospheric air entering into the pores of the soil—this effect being more marked the drier the soil. For the same reason the ground air will pass up to places where the surface is elevated, being displaced by the atmospheric air which will enter the soil in low-lying situations.

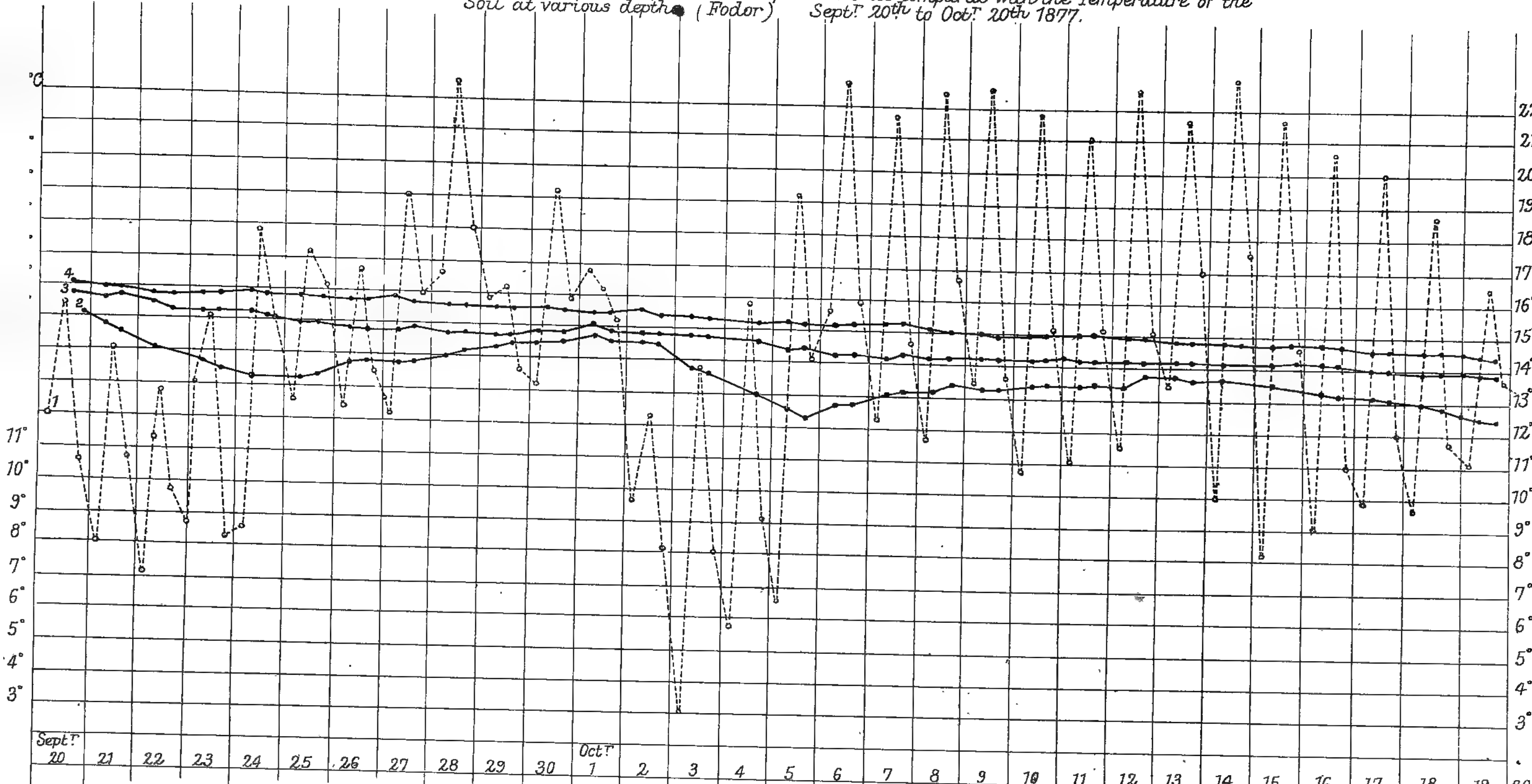
In spring and summer, on the contrary, the ground air is colder and denser than the atmosphere, hence it will tend to pass down into the deeper layers of the soil. On a cool day following on a hot one the ground air escapes into the atmosphere, while on warm days it remains stagnant in the soil. At night, too, the warmer ground air will escape into the atmosphere. Beneath buildings, such movements of the ground air may be very active, particularly in the case of houses that are artificially warmed, the air which then passes up from below being often drawn from considerable depths, so that, in the case of houses which have been built upon 'made soils' especially, much unhealthiness may result from the aspiration of foul air from the impure soil beneath, unless the precaution be taken of covering the site with an impermeable layer of asphalte or concrete, or if necessary by raising the house from the surface of the ground on arches. Similarly, leaking cesspools and drains may contaminate the soil, the air from which, passing up into houses, may most injuriously affect the health of the inhabitants.

Rain sinking into the soil will drive the ground air to a deeper level, and at the same time will cause it to escape at places where the earth has not been wetted. Variations of level of the ground water also will necessarily cause corresponding movements of the ground air which lies above it, the latter being slowly expelled from the surface of the earth as the ground water rises and occupies the spaces between the particles of the soil; air being again sucked in as the ground water falls. Other factors concerned, such as alterations of barometric pressure and the action of wind, have already been considered in connection with variations in the amount of carbon dioxide in the soil.

The air which fills the soil to a depth of from five to ten metres (15 to 30 feet) and makes up almost one-third of its volume, can, even if it move but slowly, rise therefrom in the course of a single night so as to constitute, with its contained moist foul gases, a considerable portion of the atmosphere of our dwellings, courts, and streets.

Pl. III.

Chart showing the range of Atmospheric Temperature as compared with the Temperature of the Soil at various depths (Fodor) Sept.r 20th to Oct.r 20th 1877.



Curve 1 Atmospheric Temperature
" 2 Temperature of Soil at a depth of ½ metre
" 3 " " " " 1 metre
" 4 " " " " 2 metres

The Temperature of the Air was taken at 7 A.M. 2 P.M. & 9 P.M. daily

West, Newman lith.

Estimation of Amount of Air in Soil

In order to estimate the amount of air contained in loose soils, Pettenkofer advises the following procedure:—A sample of the soil to be examined is dried at a temperature of 100° C. (212° F.) and then powdered, care being taken to crush it as little as possible. Two burettes, connected together at their lower extremities with an india-rubber tube provided with a clamp, are supported side by side on an appropriate stand; into one is put a portion of the dried and powdered soil, while the other is filled with distilled water. The first burette should now be gently tapped to expel the air as much as possible from the interstices of the soil, and the clamp opened, when the water from the second burette will gradually rise up through the soil until it appears as a thin film above the surface. As soon as this occurs, the clamp is again closed and the amount of water which has left the second burette is to be read off. The percentage amount of air in the soil is obtained as follows:—

$$\frac{\text{Cubic centimetres of water used} \times 100}{\text{Cubic centimetres of dry soil}} = \text{percentage of air,}$$

so that if 25 c.c. of soil were placed in the burette and 7 c.c. of water were used to displace the air in the soil, then $\frac{7 \times 100}{25}$ = percentage of air.

If a piece of rock is to be examined instead of loose soil, an estimation can be made in a somewhat similar manner, provided the rock is fairly porous, by determining the amount of water which it will absorb. This can be fairly accurately gauged by first weighing the rock in the dry state (x), then weighing it in water (y), and finally removing it from the water, and again weighing it while saturated with moisture (z). The calculation will then be as follows:—

$$\frac{(z-x)\ 100}{x-y} = \text{percentage of air.}$$

Estimation of Amount of Carbon Dioxide in Ground Air

For this purpose Lewis and Cunningham, who investigated the amount of carbonic acid in the soil at depths of 3 and 6 feet respectively, proceeded in the following manner. Two leaden tubes were procured, at one end of each of which a hollow perforated bulb was soldered. A pit was dug in the soil at a spot where it was perfectly free from surface pollution and where it had probably not been disturbed for many years. One of these tubes was passed through the bottom of an ordinary flower-pot, inverted and perforated in numerous places. Below and surrounding this pot fragments of earthenware were arranged so as to keep the earth from plugging the orifices in the bulbous extremity of the leaden tube. The pit was now filled up to within three feet of the surface and the other tube introduced and similarly protected from being plugged by the fine soil; the earth was then heaped up and well beaten down, until it reached the level of the surface. Observations were not made until a considerable period had elapsed, so as to allow the soil to regain its ordinary condition.

Attached to the aspirator—intervening between it and the pipe leading into the soil—were the usual appliances for estimating the amount of carbon dioxide by the baryta process, which is fully explained in another section. Briefly described, the method consists in causing the air under examination to pass through a flask containing a solution of baryta of known alkalinity, and subsequently ascertaining, by means of a solution of oxalic acid, how much of the alkalinity has disappeared after the passage through it of the air containing carbonic acid—turmeric paper being employed in preference to litmus for ascertaining the precise stage at which the solution becomes neutral.

WATER IN THE SOIL

Soil Moisture

To Pettenkofer is due the credit of having been the first to direct attention, by his important investigations, to the subject of the soil water in its relation to disease. In this connection it is necessary to distinguish between the amount of water mixed with air which is present in the interstices of the soil, known as *moisture*, and the continuous subterranean lake or sheet of water found in most soils at varying depths from the surface, known as *ground water*. Pettenkofer defines this ground water as that condition in which all interstices are filled with water, so that, except in so far as its particles are separated by solid portions of soil, there is a continuity of water.

The amount of *moisture in the soil* depends on its power of absorbing and retaining water, on the nature of the subsoil, the configuration of the ground, and the amount of water supplied by the rainfall or derived from the ground water below. It would appear that wetting of the soil, when due to a rise of ground water, will conduce to active putrefaction in the deep layers, while, the superficial layers remaining permeable, the products of decomposition can readily make their way to the surface of the earth, whereas when the wetting of the soil is due to the rainfall the conditions will be different.

The nature of the soil will influence considerably the amount of moisture which it will take up, although there is no soil which is not capable of absorbing a certain amount. Some porous soils, such as loose sands and gravels, sandstones, and chalk, are capable of taking up very large quantities; a loose sand being said to be capable of holding as much as two gallons of water in a cubic foot, while ordinary sandstone may hold one gallon. Dried quartz sand has been shown by Pfaff to have the power of retaining about 20 per cent. of water, although under natural conditions the amount absorbed would doubtless not be so great. Humus may take up as much as from 40 to 60 per cent. and retain it strongly, while chalk will take up about 15 per cent., and moderately loose clay 20 per cent. Even the most impermeable rocks, such as the granites, the metamorphic rocks, dense clays and hard limestones, will contain a certain amount of water varying in the case of the driest granites from $\frac{1}{2}$ per cent. to 4 per cent., or an average of about three gallons in a cubic yard, between which and the amount capable of being taken up by the most permeable soils all gradations are found.

Although the soil moisture is in great part regulated by the rainfall, the amount actually absorbed will depend on a variety of circumstances, such as the amount of evaporation, which will naturally be greater in summer than in winter, the rapidity of the rainfall—a large amount often running off along the surface of the ground if the downfall be severe at any one time—and the configuration of the land. In the loosest sands more than 90 per cent. of the total rainfall may penetrate the soil, while in the case of the chalk it has been calculated at 42 per cent. and with sandstone at 25 per cent. on the average, the remainder either evaporating or draining away along the surface. As has been said, the ground water also influences the soil-moisture by its variations in rise and fall, by evaporation through the upper stratum of the soil, and by capillary attraction, so that the surface soil is in these various ways kept more or less damp in all parts of the world. According to Fodor, the curve of moisture in the more superficial layers of the soil runs closely parallel with the curve representing the amount of rainfall. The curve of moisture in the deeper layers, on the other hand, runs closely parallel with

the curve representing the varying levels of the ground water, both attaining their maximum in summer and early autumn.

For determining the amount of moisture in soil, a boring is taken and weighed; it is then dried at a temperature of 110° C. and weighed again, when the difference of the two observations will represent the amount sought to be ascertained, which may conveniently be expressed as a percentage. The amount of moisture which it is *capable* of taking up may be determined by placing the previously dried soil under a bell-jar, the contained air being saturated with moisture.

In a series of observations on the amount of moisture held by soil at varying depths, Fodor found that not only did the amount decrease with the depth from the surface, but that the amount varied a great deal at all depths in similar kinds of soil, even when examined at the same time. He considers that these differences are due to the amount of organic substances in the soil, such organic substances having the effect of raising the capacity of the soil for absorbing water; this theory being borne out by the fact that the amount of moisture in the soil varies directly as the amount of organic substances present. The amount of moisture falls off rapidly as deeper layers are penetrated, and this appears to correspond also with the varying amount of organic substances in the soil, the amount of which diminishes rapidly as we get further from the surface.

The amount of moisture not only varies from year to year, but from season to season, and even from month to month, the amount generally increasing in spring, reaching its maximum in May, and then sinking during the summer till late in the autumn. Here again differences are noted according to the depth, the soil at from three to six feet from the surface being most moist in spring, the amount gradually diminishing towards autumn; while at a depth of from nine to twelve feet the soil is most moist in summer and least so in autumn.[1]

At still shorter intervals of time the variations in the amount of moisture may be very large. At from three to six feet in depth the amount of moisture usually remains constant, since, in fact, the soil at these depths is generally saturated. Below these levels the sinking rain-water will probably first saturate the soil, and then running off again, will in turn leave it relatively dry. It is, however, the variations in the layers down to about six feet below the surface especially that are of most interest practically, since these upper layers will naturally be the most polluted, and because, therefore, processes which influence health probably go on in them to a much greater extent than in the layers below. The minimum moisture found at Buda-Pesth at one yard from the surface was 5·9 per cent. or 59 grammes of water per 1,000 grammes of soil, while at four yards it was 3·2 per cent.; but since decomposition continues when there is only 2 per cent. of moisture present, and is very active when the amount reaches 4 per cent., it is obvious that, as far as moisture is concerned, oxidation and putrefaction are particularly favoured at the former level, while they are less so at greater depths.

Ground or Subsoil Water

A continuous sheet of water, termed *ground water*, is found below the surface of the soil, at depths which vary very considerably in different localities, as occasionally it may reach to within a few inches of the surface, while in other cases it may only be met with at a hundred or more feet below it. This difference in level will depend on the permeability of the soil, on the nature and inclination of the strata below the surface, whether loose or compact, and on

[1] These statements refer more particularly to Buda-Pesth, where Fodor's experiments were carried out.

the ease or the reverse with which the water can flow away to some outlet in springs, rivers, or the sea. The water is in constant movement in its endeavour to reach such outlets, and the variations in the level of the ground water caused by such flow is best studied by taking measurements of the level of water in wells, as has been done in a most exhaustive manner by Pettenkofer, Fodor, Baldwin Latham, and others, who have insisted strongly on the importance of such variation of level of the ground water as constituting a weighty factor in the etiology of certain diseases, such as cholera and enteric fever.

Fodor found that at Buda-Pesth such variations were regulated over the greater part of the city by the varying level of the Danube, the greatest fluctuations being found in the wells nearest the river; while, on the other hand, the greater the distance from the Danube the smaller were the variations of the water level, until at the outer limits of the city they almost entirely disappeared.

Although the level of the ground water is thus constantly changing, the difference between its highest and lowest levels is usually not more than a few feet, while in some instances the range of movement may be only a few inches either way. At Munich a difference of ten feet has been noticed, and in India it is often much more than this, a range of $42\frac{1}{4}$ ft. having been recorded. Fodor noted seasonal variations of the ground-water level which, however, agreed very closely with variations in the level of the Danube; the ground water and that of the river rising and falling, and reaching their maximum and minimum at the same time.

The rise was noticeable at the beginning of July and continued through August, the highest level in each of three years occurring about the middle of summer, and the lowest at the end of winter and beginning of spring; so that the interesting fact was brought out that the ground water is highest when the rainfall is smallest. This was particularly noticeable in May 1887, when, after an exceptionally heavy rainfall, no marked influence on the variation of level of the ground water in any one of the wells could be detected: the reason being that the extent of the subsoil water at Buda-Pesth is affected to a much greater extent by variations in the level of the river than by merely local rainfall. It must not, however, be supposed that the rainfall never affects the ground water, as in some instances it undoubtedly does so; but even then the effect may not be visible until some considerable time afterwards, extending to weeks or even months. On the other hand, in low-lying situations, such as in plains at the foot of hills, the level may be raised by rainfalls occurring at far distant spots. The level will also be raised by any obstruction at the outfall, such as may be caused by the silting up of a watercourse, or the backward pressure of the sea, and, on the other hand, it will be lowered by any removal of obstruction, such as may be secured by skilful drainage. The immense distance at which pressure may be exerted on the subsoil water is shown by the fact that the Danube at Buda-Pesth was found by Fodor to influence the level of the water in a well at a distance of 2,700 feet from that river. De Chaumont also instances a place on the Hamble River in Hampshire, where the tide was found to affect the water of a well at a distance of 2,240 feet, the well itself being 83 feet deep and 140 feet above mean water level. Similarly, the water of a well was affected by the pressure of the water of the Rhine at a distance of 1,670 feet.

The ground water is constantly moving in a horizontal direction, usually flowing towards the nearest watercourse or the sea; the rate of movement depending on the inclination of underlying impervious strata, and the ease, or the reverse, with which it can eventually escape, so that it varies greatly

in different places. Its rate of movement is also influenced by the roots of trees, as when trees are removed it runs away much more rapidly. As the mean of a large number of measurements as to the time when a rise in the Danube was followed by a rise of water in the wells at Buda-Pesth, Fodor found that the mean rate of movement of the ground water was 53 metres, or 174 feet, in twenty-four hours, with a maximum of 66 metres, or 215 feet, in the same length of time. In Munich, Pettenkofer reckons the rate of flow as fifteen feet daily, while high water in the Elbe is stated to move the adjacent ground water at the rate of seven or eight feet daily.

The height to which the ground water extends is measured by noting the level of water in wells in the locality in which the investigation is to be carried out. For this purpose, Pettenkofer recommends that a rod or rope, to which a number of small cups are fixed at equal distances, should be lowered into the well. On drawing them up again, the highest one which contains water will obviously denote fairly accurately the height at which water stands in that particular well, and if the length of rod which has been lowered is noted, the distance from the surface to the water level will be found. To arrive at any correct estimate of the true ground-water level, a large number of experiments must be carried out simultaneously in the wells over a considerable area, so as to obviate sources of error arising from local conditions. To be of any real use, such observations should be made as frequently as possible; those from which Fodor derives his conclusions having been made every week in a large number of adjoining places, the series extending over a period of several years.

Another method, given by Pettenkofer for the determination of the level of well water, consists in the use of a large float, suspended by a chain passing over a pulley, which is connected with a counter-balance, having an indicator attached to it, which marks the height on a fixed scale which has been previously experimentally graduated for the length of the chain.

THE TEMPERATURE OF THE SOIL

Different soils vary very considerably in the extent to which they are capable of absorbing heat, this depending mainly on the looseness or density of the particles and on the colour of the soil; but, in most places, variations of temperature dependent on that of the atmosphere may be found to extend in this climate to a depth of about sixty feet, and even deeper in other portions of the globe. These variations of temperature at all depths do not, however, follow directly on similar fluctuations in the atmospheric temperature, such changes being delayed longer and longer in the lower layers of the soil, so that it is only at the surface that there is any immediate correspondence between the temperatures of air and soil. This point is well brought out by Fodor, who found that the warming and cooling of the deeper layers was much slower than the warming and cooling of the atmosphere, or of the superficial layers of the soil; his observations at Buda-Pesth giving the following results:—

The average maximum temperature at a depth of ½ to 1 metre was found in August.
" " " " 2 metres was found in September (and August).
" " " " 4 metres was found in October (and September).
The average minimum temperature at a depth of ½ to 1 metre was generally in February and January.
" " " " 2 metres was found in April; in some cases in March.

He also found that the greatest range of temperature was noted in the superficial layers; at half a metre below the surface there was a variation of even 20° C. below the monthly means of one and the same year, but at a depth of four metres there was a variation of $5\frac{1}{2}$° only, and in some places of hardly more than 3°. The temperature at this depth was very uniform, rising and falling very slowly, seldom varying as much as half a degree in the course of ten days. It changed most rapidly in the spring, and when it reached either its maximum or minimum it usually remained constant for ten, twenty, or even more days, rising to the maximum and falling to the minimum at an average rate of from $\frac{1}{10}$° to $\frac{2}{10}$° C. every ten days. In the upper layers, however, the variations occur more rapidly. At a depth of two metres there may be a change of $2\frac{1}{2}$° C. in ten days, while the variations are still greater at a depth of one metre or less.

Different soils vary considerably in the rapidity with which they are influenced by the atmospheric temperature; that is, they differ in the rate at which a rise or fall of temperature takes place in them. The temperature of the *surface soil* will depend greatly on whether the sun shines directly on it, as in this case a higher temperature will be recorded than that of the atmosphere above, and in this way the atmosphere just above the surface may receive much of its heat from the soil. When, on the other hand, the sun's rays no longer fall on the soil, it readily loses heat, and may, at night, possess a lower temperature than that of the air. When this takes place, the moisture contained in the air condenses upon the surface in the form of dew.

The soil temperature below the surface follows even great variations of air temperature but slowly, for after a succession of warm or cold days, it needs two or three days for the temperature, at a depth of half a metre, to begin to accommodate itself to that of the atmosphere. Indeed, a change of from twelve to fourteen, or even more, degrees in the atmospheric temperature from one day to the next may not be followed by a change of even 1° C. in the temperature of the soil half a metre below the surface. At a depth of one metre the changes are still smaller, while at two or four metres' depth the increasing or decreasing soil temperature moves almost in a straight line, although the record of the air temperature may show a zigzag curve.

These statements receive confirmation from the observations of Lewis and Cunningham at Calcutta, who found that fluctuations in temperature in the upper layers of the soil follow those of the atmosphere very regularly, except during the recurrence of rain, when this correspondence was not constant. Their observations were taken at depths of three feet and six feet respectively. The fluctuations in the temperature of the lower layer were much less marked and sudden than in the more superficial, the line of elevation and depression following a long gentle curve. They found also that the maxima of temperature in the two layers approached more closely than the minima, a point in which the relations of temperature corresponded with those of carbonic acid. During cold weather the temperature of the lower layers considerably exceeded that of the upper one, while this in turn was higher than that of the atmosphere, these relations being exactly reversed in hot weather, when the temperature of the upper layer was the highest, that of the deeper layer of the soil the lowest.

Different geological formations vary very much in their power of absorbing and conducting heat, and the radiating power of the soil, which is not necessarily equal to its power of absorption, will depend somewhat on the colour of the soil and also on the kind and thickness of the vegetation.

That the temperature of the soil should depend to a certain extent on its

colour, follows from the well-known fact that dark substances possess the greatest power of absorbing heat rays, as may be shown by the oft-quoted experiment of placing two pieces of paper, the one white and the other black, on the surface of snow when the sun is shining on it, when it will be found that the snow melts more rapidly under the black paper than beneath the white piece.

In like manner, the darker the soil, the more rapidly does it absorb heat from the sun, very light-coloured soils, such as those containing much chalk, heating but very slowly. Seeing that the colour of the darkest soils is for the most part due to the products of decomposition of organic substances, it follows that the warmest soils will be those which are richest in humus. This result will also be increased to a certain degree where decomposition processes are going on in the soil because of the heat thus produced, while also, since on a warmer soil vegetation will be more luxuriant and growth proceed at a greater rate than elsewhere, an additional appreciable amount of heat will result, small though it may be; it having been proved by numerous observers that the growth of plants is always accompanied by a rise of temperature, which, again, is related to the rapidity of their vital processes.

The following table, condensed by Lloyd from a much fuller one compiled by Liebenberg, of Halle, shows both the rapidity with which heat is gained by various kinds of soil and also the rate at which it penetrates beneath the surface :—

Gain of Heat by Soils

—	Original temp.	After ½ hour		After 1 hour		After 2 hours	
		2 cm.	5 cm.	2 cm.	5 cm.	2 cm.	5 cm.
Lime sand	21° C.	29° C.	27·5° C.	32° C.	31·5° C.	36·5° C.	37° C.
Tertiary clay	21	30·0	27·5	33·0	30·0	36·3	35·0
Tertiary sand	21	30·0	28·0	33·5	32·5	37·5	36·5
Marl	21	31·0	28·5	34·5	32·5	39·0	37·5
Meadow loam	21	32·0	27·5	37·0	36·0	40·5	38·5
Rich loam	21	32·5	29·0	36·0	34·0	41·5	39·5
Basalt soil	21	33·0	28·5	35·0	33·0	42·0	38·0
Water	21	26·0	26·0	29·5	29·5	31·0	31·0

This table shows not only that sand becomes warmed throughout more rapidly than clay, but also, as stated above, that the richer a soil is in organic matter, the greater the power it possesses of absorbing heat. It further shows that the temperature of water increases but slowly, which probably accounts for the fact that soils containing much water are colder than those which are comparatively dry; and indeed it has been established by observation that the damper the soil, the slower it is to become warm, which accounts for the differing behaviour, as shown in the table, between sandy soils, which are dry and warm, and clay, which retains a large amount of moisture. Not only do clay soils warm slowly, but they also rapidly lose their heat, whereas sandy soils on the contrary retain their warmth for a considerably longer time. The results of some experiments by Liebenberg are shown in the following table :—

Loss of Heat by Soils

Nature of soil	Original temp.	After ½ hour	After 1 hour	After 2 hours
Coarse sand	41·25° C.	29·75° C.	24·25° C.	19·75° C.
Fine sand	41·75	28·25	23·25	18·75
Marls	40·00	27·50	23·00	18·50
Loams	40·00	27·00	22·00	18·00
Clay	39·50	26·00	21·50	18·00

The following table by Schübler shows the results of his observations on the power possessed by various soils of retaining heat, a power dependent partly on the physical properties and partly on the chemical composition of the soil :—

Power of retaining Heat, 100 *being assumed as the Standard*

Sand, with some limestone	100	Clayey earth	68·4
Pure sand	95·6	Pure clay	66·7
Light clay	76·9	Fine chalk	61·8
Gypsum	72·2	Humus	49
Heavy clay	71·1		

Usually radiation takes place more rapidly than absorption, particularly where herbage is abundant, so that soils cool more rapidly than they heat. Jourdanet cites a remarkable instance of this which was noticed in some of the marshes in Mexico, which cool so rapidly at night that the evolution of malaria is prevented, the marsh consequently not being dangerous at night. On one occasion when the air temperature at a height of sixteen feet from the ground was 58° F., that of the marsh at the ground level was only 32° F. The effect of herbage on both the radiating and absorbing power of the soil is often very great, a difference of as much as 30° F. having been recorded in a tropical climate between the temperature of a naked rock and an adjoining one which was covered with grass.

The effect of soil temperature on disease was first described by Delbruck, who called attention to its importance in connection with an epidemic of cholera at Halle in 1867 which appeared to be associated with a maximum soil temperature combined with a certain degree of soil moisture. It doubtless also influences the spread of malaria, while recently Ballard has demonstrated its important relations with the occurrence of summer diarrhœa. Pfeiffer, Küchenmeister, Fleck, and Fodor have also investigated this subject.

Estimation of Soil Temperature

The method by which their observations on the temperature of the soil was carried out is thus described by Lewis and Cunningham. A shallow shaft or well of sufficient capacity to allow of easy entrance was sunk in the soil to a depth of slightly over six feet, and was lined with bricks and mortar. An opening was left in the floor to allow of drainage of any surface water which might obtain entrance, and two openings were left in the brickwork of one side of the shaft at depths of three and six feet respectively leading into wide tubes of perforated zinc, which penetrated the soil horizontally from the outer surface of the brickwork and terminated in open extremities in the earth. These tubes were of sufficient diameter to allow of a narrow board, carrying the thermometers, being pushed into them. The thermometer board had a wooden plug and handle which fitted into the mouth of the tube, whilst the opening in the brickwork was closed by an accurately adjusted wooden cover, and further secured by being coated externally with moist clay.

A thick wooden lid, covered with a layer of turf, closed the mouth of the shaft, and the entrance of rain or access of sun to the cover was prevented by a thatch roof about five feet from the ground.

Observations were made at the same hour every day, and the thermometers immediately returned to their places in the perforated zinc tubes let into the earth, care being taken, before returning them, to raise the temperature of the minimum, and to depress that of the maximum instrument considerably above and below the temperature of the soil.

Fodor advises that the thermometers should be placed in a two-inch tin tube, the interval between the thermometer and the casing being filled in with fine sand.

DISEASES ATTRIBUTED TO CONDITIONS OF THE SOIL

The permeability of the soil, its composition and that of the ground air, the amount of heat and moisture present, and the variations in level of the subsoil water, have been found by numerous observers to bear important relations to many of the diseases which afflict mankind, while the lower animals are also, though perhaps in less degree, liable to suffer from like causes.

Coincident with the disappearance of oxygen from the ground atmosphere an equivalent amount of carbon dioxide is produced, which when the pressure of the air above ground is increased, or when the temperature is lowered, penetrates the soil. This drives out before it the ground air, which may thus enter the cellars and basements of houses, from which it will probably ascend, through the influence of convection currents, to the upper stories. A similar effect has been shown to occur in consequence of heavy rains, the water filling up the interstices of the soil near the surface, and so forcing down the gases in the soil, which will then escape at places where the ground is dry, as under buildings, this effect being the more likely to happen the greater the porosity of the soil.

Many basement dwellings extend from three to ten feet below the surface of the ground, and seeing that at a depth of thirteen feet (four metres) the amount of oxygen present in the air entering them from below may be from one-third to one-half of the normal percentage, the carbon dioxide is increased inversely as the amount of oxygen present. Accordingly, it is evident that the danger incurred by the inhabitants of such dwellings may be very much the reverse of imaginary, particularly if the soil be much polluted with organic matter. This will be the more readily appreciated when we remember that the soil, and so the ground air also, teems with micro-organisms of various kinds, some of a pathogenic nature. These, when the soil is dry, being carried in various directions by the currents of ground air, and finding exit at the surface, may affect the atmosphere of the immediate or of contiguous localities, or may be carried to considerable distances from the spot where they originated. If, on the other hand, such diffusion is prevented by the effects of the pressure or temperature of the air above, or by a blocking of the upper layer of the soil by water, they will tend to be carried directly into buildings along with the impure ground air.

In spring and early summer, however, the ground being cooler than the air above, the ground air, being in consequence denser and heavier, is not so easily displaced as at other seasons of the year. In autumn, on the contrary, the ground air is displaced with greater ease, and so is more likely to be forced out from the interstices of the soil into the atmosphere above. These facts would afford an explanation of the comparatively slight prevalence, in spring and early summer, and greater prevalence in autumn, of certain epidemic infectious diseases which may be thought to depend on movements of the ground air. Similar conditions may, perhaps, explain also the greater likelihood of infection at night, which is believed to occur in connection with such diseases as malaria and yellow fever (Rohé).

The level of the ground water and the amount of moisture in the soil above it, have been shown to have a considerable influence on the extent of the putrefactive processes going on in the soil, and these in towns will influence

the composition of air and drinking water, and so directly or indirectly the health of the population of the district. Thus dampness of the surface will cause a cold soil and a misty air, and as a result, perhaps, encourage such diseases as paroxysmal fevers, rheumatism, neuralgia, and various lung affections. On the other hand, certain dry and apparently pure soils, which would usually be considered healthy, are apt to cause malaria, the reason for which is not very evident; it may, however, be explicable in the manner already suggested, that the porosity of the soil allows the transference of contaminated air from considerable distances.

In several of the diseases held to be related to telluric conditions, recent researches have shown that definite micro-organisms are invariably found in the blood or tissues of affected persons or animals, although the exact *rôle* played by such microphytic forms in the causation of disease has not been in most instances at all certainly determined. It is, therefore, highly desirable, not only that the life history of these bacteria should be studied in the body of their host, but also that diligent search should be made for them among the numerous micro-organisms which are always to be found in ordinary surface soil, so that the relations of environment to their destruction or special multiplication at any given time and place may be as nearly as possible determined. Some observers have thought that under certain circumstances bacteria ordinarily harmless may take on pathogenic properties, and although the weight of evidence may be against this, it seems hardly possible, on any other assumption, to explain the sudden appearance of a given disease in absence of all apparent relation to pre-existing disease of like sort, or to explain the various types presented by one and the same disease in different epidemics. As Buchanan says, 'Looking to the prodigious part that bacterial life plays in the economy of nature, it is hardly too much to expect that morbific bacteria may come hereafter to be known, not merely as producing disease under certain conditions, but as having, under other conditions, many other functions in that economy.' 'Whether, and if so where, and under what conditions, the bacilli found in tubercle, for instance, exist elsewhere in some harmless state, and by what change of conditions they can become morbific, are problems of the highest importance.' We know that under conditions of artificial cultivation, which have been carefully studied of late, it is possible to so reduce the virulence of many pathogenic bacteria that ultimately their injection into the living body is practically without appreciable effect, and fails even in conferring immunity against the subsequent action of more potent cultures; is it then beyond the region of possibility that such organisms under certain other conditions may once more regain their original pathogenic properties after a temporary stage of suspended function, in a reverse manner to that in which these properties were originally lost; that such changes should be capable of occurring in the interstices of the soil as well as in the culture-tube of the bacteriologist?

Investigations on these lines promise not only information as to the production of disease, but knowledge also of methods of preventing disease, which is the primary aim of sanitary science. Much has already been done, but much still remains to be done before what we think we know can be considered to possess firm basis of fact. In the following pages are given the results of research up to the present time on the relation to soil-conditions of certain diseases; but unfortunately the subject is still to a considerable extent veiled in obscurity, so that, even as regards not a few diseases in which such connection would appear most indisputable, we are as far as ever from a knowledge of how best to combat the malign influences that confront us.

Typhoid or Enteric Fever

Although until comparatively recent years this disease was confounded with typhus, we have evidence that it has asserted its presence in more or less virulent forms for at least the last two hundred years, Baglivi and Lancisi having described cases, apparently of this disease, which occurred at Rome at the end of the seventeenth century, but which, however, they believed to be a form of ague. It is also of interest that Dr. Norman Moore has proved from the memoranda of Dr. Mayerne, physician to James I., that the disease of which Henry, Prince of Wales, died in 1612 was enteric fever.

The chief credit, at any rate in this country, in demonstrating the differences between typhoid and typhus fevers is undoubtedly due to Dr. A. P. Stewart, who, as the result of his observations, came to the conclusion that the differences between the two diseases were 'so marked as to defy misconception, and to enable the observer to form with the utmost precision the diagnosis of the nature of the disease and the lesions to be revealed by dissection' (1840). Strother, however, in 1729, first gave a description of the anatomical characters of the disease, which, he says, is a 'symptomatical fever arising from an inflammation, or an ulcer, fixed on some of the bowels.' The fact of this disease affecting specially the bowels obviously gives special opportunity for fouling the earth, and so for the passing on of the disease to other persons.

In certain places typhoid appears to be *endemic*, but elsewhere its prevalence has been proved for the most part to be largely due to the movements and intercourse of human beings, numerous instances having been placed on record in which outbreaks occurring in localities previously entirely free from the disease have been traced to the arrival of a patient already suffering from enteric fever, opportunity having been thus afforded for specific contamination of the soil. Murchison and others have, indeed, affirmed the disease to be capable of arising *de novo* when surrounding conditions were favourable thereto, supporting their view with numbers of cases in which the most exhaustive inquiry had failed to elicit any trace of a pre-existent human case. This theory, however, finds little acceptance at the present day, and later writers have attempted to explain Murchison's cases on the supposition that the bacillus which is believed to be the exciting cause of the disease is a vegetable parasite having an existence independent of the human subject, capable of completing its life-cycle, and of reproducing itself, if not in some other animal body, in the earth or atmosphere. If this be so, one may thus account not only for those cases occurring in this country which it has been impossible to trace to infection from one person to another, but also for the fact that travellers have been stricken down with this disease in tropical countries believed to be entirely uninhabited.

For the most part, however, typhoid undoubtedly spreads indirectly through the stools from one or more specific cases of the disease, infecting drains, sewers, cesspools, or the soil itself, by which means the drinking water, air, or food become contaminated, and thus secure propagation of the malady in various directions; the water, of course, usually becoming infected from having passed through already polluted earth. By the admixture of such water with milk, or from dairy utensils having been washed out with it, we have other means by which the disease may secure further victims.

For the system to be affected with typhoid, the essential cause of the malady must doubtless gain access to the alimentary canal, a possible way being that the dust of dried excreta may be carried in the air to the mouth, and then swallowed with the saliva; but the more frequent channel is

undoubtedly by the ingestion of drink and food. So great a mass of evidence has been collected on this point that the fact has well-nigh been lost sight of that in many cases the drinking water, for instance, is only the vehicle, the soil itself being the situation not only from which the poison is immediately derived, but one in which it is capable of lying dormant for an indefinite period. A case which illustrates this point is related by Von Giett. A man who had acquired enteric fever elsewhere brought it to a village. His evacuations were buried in a dung-heap. Some weeks later five persons engaged in removing some of the dung were attacked by the disease; their discharges were sunk deep in the heap. At the end of nine months it was completely cleared out by two workmen, one of whom fell ill of enteric fever and died.

Murchison also states that he has seen single cases of enteric fever arising in the same house again and again at intervals of a year or longer. In such a case it is obviously unnecessary to suppose that on each occasion the specific poison had been brought afresh to the place, it being much more likely that the germs of the disease had been present during the whole period, and had from time to time been roused to increased activity by the changing influence of their environment. Several instances also have been recorded in which boys who had watched the clearing-out of the soil around old and imperfect drains had shortly afterwards been smitten down with the disease.

In many country villages typhoid has been known to break out every autumn, although no sanitary defect could be discovered. In such cases it is probable that a large area of the soil is polluted, and thus, particularly where the water-supply is derived from surface-wells, it is impossible to secure immunity from the disease unless an entirely different source of water for drinking purposes be provided.

An instance of an outbreak of enteric fever, traced to the contamination of milk with such a water-supply, is seen in Dr. Ballard's report of his investigations at Armley, near Leeds, in the summer of 1872. He found that all the early cases, with one exception, had been supplied with milk from the same dairy, which had been mixed with water obtained from a pump on the premises. He found, moreover, that about a month before the epidemic appeared the dairyman had himself been ill with typhoid fever, and that his excreta had been deposited in a privy, the drainage from which escaped into the soil. From thence fæcal matter had apparently been washed by heavy rains occurring at the time, into the well from which the pump was fed; this supposition being borne out by the fact that at the bottom of the well a layer of filthy mud was found from which bubbles of gas escaped when it was disturbed, while from the sides of the well next the privy a similar black material was found to be oozing.

The prevalence of typhoid fever is markedly affected by seasonal and climatic influences, the greater number of cases in this country occurring in the autumn, and being, in particular localities, especially large when the preceding summer has been hot and dry, while, on the other hand, if the summer has been damp and cold, the disease will not attain so high a point. The statistics of the London Fever Hospital for the years 1848–1870 inclusive show that the number of admissions was greatest each year from August to November, while it was least in April and May. Buchan and Mitchell, dealing with enteric fever deaths, state that, taking the average of a large number of years, the maximum point is reached in the last week in October, while the disease does not fall below its average until the last week in February, attaining its absolute minimum from the middle of May to the end of June.

Observations made on this subject in Berlin and Basle also show a

similar relation between intense summer heat and excessive prevalence of typhoid, the maximum amount of fever in these places also occurring two or three months later than the maximum temperature, while at Munich the retardation is more marked, the greatest number of deaths occurring in February. Fodor shows that at Buda-Pesth the number of deaths usually rises in winter and spring, the severest epidemic that has visited that place—that of 1864–65—having reached its maximum in January, and from these facts he argues that, since the typhoid curve shows no relation to those of either temperature or of CO_2 production, the prevalence of the disease is not dependent on putrefactive processes going on in the superficial layers of the soil. These results are arrived at by comparing the death curve with the condition of soil at the time of infection, or at a period of from four to five weeks previous to the termination of the disease, thus allowing for (1) incubation about two weeks, though it is often much shorter—Zelindes, for instance, stating that in pregnancy it may only be from twenty-four to forty-eight hours; and for (2) period of illness preceding death, which Murchison found, as an average of 112 cases, to be as nearly as possible 27½ days.

Although no pronounced relation could be found between the death rate and the temperature or putrefactive activity of the soil, Fodor has demonstrated an apparent close connection between the typhoid curve and one representing variations in the level of the Danube, both these curves, almost without exception, rising and falling together. Thus at the begining of 1872, both of these curves rose simultaneously, attained their acme in the middle of the year, and then both fell off in a like manner. In this connection it must be remembered that the level of the Danube exerts a very regular influence on the ground-water level throughout the greater part of the town, and thus it would appear that in Buda-Pesth typhoid is most commonly related to a rising level of the water in the soil. In Munich, where Buhl applied the observations of Pettenkofer on cholera to the incidence of typhoid, and in Berlin, on the other hand, the reverse phenomenon has been recorded, the disease in both places increasing as the ground water falls. This latter state of things has been referred to a more active decomposition of organic material in the more superficial and polluted layers of the soil, following on the abstraction of a certain amount of water from the earth, and possibly this explanation may be correct as regards Berlin, where outbreaks most commonly occur in autumn. In Buda-Pesth, however, as already stated, the disease is usually more prevalent in winter and spring, and seeing that there is often so close a connection of epidemic enteric fever with variations in level of the ground water, we may perhaps infer that it is there influenced to a certain extent by processes going on in the deeper layers of the soil, those layers indeed in which the rise or fall of the ground water is felt.

Liebermeister and Buchanan, with considerable reason, have supposed that soil-water observations simply illustrate the communication of the disease by means of drinking water; the water of surface wells being generally more impure when the level of the soil water is persistently low, when also there will be more likelihood of noxious matter accumulating in the stagnant water in the soil.

Rainfall, and the consequent wetting of the superficial layers of the soil, has obviously no influence in regulating the spread of typhoid, since the disease may prevail to an equal extent whether the surface of the earth is dry or the reverse, and this even when the wetting of the upper stratum is markedly related to the amount of the rainfall.

Seeing, then, that at Buda-Pesth at any rate, and perhaps at Munich, there is proof of a close relation between the extent to which typhoid prevails, and

the variations in level of the ground water, but to no other meteorological state, it would be well to compare the conditions in Buda-Pesth with those in other cities in which this subject has been investigated, the following points being those which appear specially worthy of note :—

1. That the ground water in that town lies for the most part near to the surface, especially in those parts which have suffered most from typhoid.

2. That the variations of level are very small, and that they are regulated by the level of the Danube.

3. That the horizontal movement of the ground water is very slow; and,

4. That, in consequence of this movement being particularly slow, the water stagnates in the polluted soil in those parts of the town which suffer most severely when the Danube rises.

At present, however, but little is certainly known as to the influence of telluric conditions on the prevalence of this disease, and further research is needed before any dogmatic statement can be made; but notwithstanding the obscurity which still hangs over this subject—an obscurity increased by the fact that Buhl's law, or the converse proposition as enunciated by Fodor, is, as it seems, applicable to certain places only, having no relevancy for others—no one can deny the importance of the soil as the breeding place of the typhoid poison. No doubt, as Hirsch says, typhoid may develop under circumstances where any influence of the soil is not only highly improbable but even excluded as an etiological factor altogether, as in epidemics in rooms. But those cases are by no means in contradiction of the theory; they serve rather to corroborate it, inasmuch as the same conditions that cause or assist the typhoid poison to ripen or acquire potency in the soil may be met with also outside the soil. As Lindwurm very justly says, 'What the soil is on a large scale, the same on a small scale are also the floors of rooms, the walls of houses, the drains of privies and the like. Just as it matures at some depth in the ground, so also may the typhoid germ obtain the necessary conditions for its growth in a seam or cleft in the flooring of a room, or in the loosened mortar and sand between stones and slabs.'

The Typhoid Bacillus

To Eberth, Gaffky, Klebs, and Koch we owe the discovery of a specific microbe which is at the present time believed to be the essential cause of typhoid fever. Prior to the publication of their researches, Recklinghausen, Klein, Browicz, Fischel, and other observers had described colonies of micrococci which they had found in the mucous membrane of the intestine, in the kidneys, the spleen, and even in the muscular tissue of the heart, but the presence of these cocci was probably merely accidental and had no relation to the occurrence of the disease.

There is great difficulty in obtaining the specific bacillus from typhoid stools, because of the large number of other micro-organisms which are present, and which in the course of their growth liquefy the gelatine. Chantenesse and Widel, however, have shown that if trichloride of iodine be added to the gelatine in which the cultivation is made, the growth of the ordinary putrefactive organisms is aborted while the typhoid bacillus is unaffected. A similar result may be obtained by keeping the growth at a temperature of about 45° C., at which the typhoid bacillus alone is capable of existing, or by adding to the culture medium a small quantity of carbolic acid.

By adopting one or other of these methods, the presence of the typhoid bacillus has been detected in water known to have caused an outbreak of

fever even when chemical analysis failed to indicate any serious organic contamination. In an epidemic investigated by Bonner, he was unable to find the bacillus in the water of a well supposed to have caused the outbreak, but found it abundantly in the *soil* in the neighbourhood of the well.

Inoculation experiments with the bacillus on animals have not up to the present met with much success.

'The prophylactic measures against the spread of typhoid fever comprise isolation of the sick, prompt disinfection and careful disposal of the discharges, and cleanliness in the widest sense. The water and food supplies must be carefully guarded against contamination with the poison, and all decomposing animal matter and excreta must be removed from the immediate vicinity of dwellings. The requisites for prevention may be summed up as pure air, pure water, uncontaminated food, and a clean soil.'

Diphtheria

Although not long since mainly prevalent in rural districts, diphtheria is a disease which of late years has unfortunately become exceedingly prevalent in towns as well, London now showing a greater rate of mortality from this disease than any other district in England and Wales. It was not until 1855 that it came at all prominently into notice, in which year, and those immediately following, numerous outbreaks occurred in various parts of England, since when, to quote Dr. Thorne Thorne's words, it has been an almost continuous and, generally speaking, an increasing cause of death amongst us. This is strikingly shown by the fact that within the last twenty years the total annual number of deaths from diphtheria in England and Wales has more than doubled, while in London it has more than trebled in the same length of time. It is of course possible, however, that the previous excessive prevalence in rural districts may be only masked at the present time by some cause common to large centres of population, such as personal contagion.

In 1859 the Medical Department of the Privy Council undertook a somewhat extensive inquiry into the subject, as the result of which it appeared that the disease prevailed for the most part, although not entirely, in damp and marshy situations and on cold wet clay soils. Dr. Greenhow also reported that associated with it he had found a marked prevalence of certain diseases affecting the nasal and buccal mucous membranes of certain of the domestic animals, such as cattle and horses, although he did not succeed in tracing any definite connection between such affections and the disease in human beings. In these observations he paved the way for the recent discoveries of Roux and Yersin, Klebs, Löffler, and Klein, by whom it has been determined that there is an intimate relationship between human diphtheria and a somewhat similar disease affecting certain of the lower animals, particularly cats.

The possibility of such a mode of infection may perhaps account for the fact that it has often appeared impossible to trace any cause to which an outbreak could be attributed. Dr. Airy, who in 1880 undertook an inquiry for the Local Government Board, was particularly struck with this point, and he, in this connection, recalls the opinion of Prof. Burdon Sanderson, who in 1859 reported that 'the circumstances were permanently such as to shut out even the possibility of personal communication.' Dr. Airy further reported that the disease was more prevalent on clayey than on sandy soils, that its incidence was greatest on persons liable to throat affections, and further that the only view which appeared consonant with all the facts which he had gathered together, was that which attributed the affection to

a living organism capable of infecting milk and air and of being transmitted by wind currents.

This view of the carriage of diphtheria infection by milk has received support from several investigations on the subject, notably in one conducted by Mr. Power during an epidemic of diphtheria in North London in 1878, in which it appeared probable that the cow herself might have been concerned in the infection of the milk. A like difficulty in referring the outbreak to a human source is seen in a report by the same gentleman concerning an outbreak about ten years later at York Town and Camberley, although its relation to disease of the cows belonging to the dairy farm from which the milk was obtained seemed almost as indefinite. A similar possible source of infection is suggested in reference to an outbreak investigated by Mr. Power at Hendon in 1883, Dr. Buchanan saying in his report for that year that 'at Hendon it was difficult to refuse this explanation of the facts, since the milk at the very time it was operative for harm . . . exhibited a peculiar ropiness and unpleasant taste which caused some of its habitual consumers to return it to the dairy; and for these phenomena, no condition about the dairy or its utensils could be regarded as responsible.'

Prior to this, however, Dr. Thursfield, in a series of papers contributed to the *Lancet* in 1878, had expressed his opinion that diphtheria, essentially a disease of rural districts, otherwise the most healthy as indicated by the fever death-rate, was intimately connected as regards local conditions with structural dampness of habitation. This statement, at the time, being contrary to accepted ideas, was severely challenged by those who maintained that typhoid fever and diphtheria alike were the result of exposure to filth accumulation, and that the explanation of the special incidence of diphtheria upon rural districts, which was at that time apparent, was due to the fact that the towns had relatively made more sanitary progress than the country districts. Dr. Simpson, in reporting on an epidemic at Shaftesbury in 1885, refers especially to an outbreak in three successive Novembers in an old dilapidated house standing on a water-logged soil, where the walls of the ground and upper floors were found to be wet and covered with moulds, and the woodwork rotten.

That structural dampness of dwellings is a most important factor in the development of diphtheria is now generally admitted, such a condition being most favourable for the incidence and severity of the affection and the persistent vitality of the germ of the disease. As Dr. Thursfield has pointed out, this dampness of houses may depend on the subsoil water being so close to the surface that the cellar always contains more or less water, or upon the house being built upon a retentive clay without the precaution having been taken of providing a damp-proof substratum, but even more frequently, upon the house being deeply embedded at the back or slightly all around. The material of which a house is built may also be conducive to a similar result, a porous absorbent stone retentive of moisture being very favourable to the incidence of the disease. Trees surrounding and shutting in the house will naturally aggravate the liability to the deposition and retention of moisture, provided that the materials of which it is built are of a nature favourable to such conditions.

Although dampness of site is undoubtedly a factor in the production of outbreaks of diphtheria, particularly if such dampness be due to persistent leakage from imperfect sewers or cesspools, it does not appear that there is any direct relation between the occurrence of an epidemic and a rise or fall of subsoil water, provided that the structure and atmosphere of the houses are not affected. Many districts, which although usually dry are liable to

occasional floods, are remarkably free from the disease, so that it appears that a persistent impregnation of the soil with moisture is of more importance than fluctuations in the height of the ground water, particularly if these have any considerable range.

It should be stated that Bruhl and Johr claim to have proved that an increase of mortality from this disease is closely connected with prevalent atmospheric conditions, the maximum mortality being in those places where there is throughout the year less equability of temperature and humidity of the air. Where these conditions are more equable, or where the air is warm and dry, the mortality is lowest. These statements are perhaps not so much at variance with the view already advocated as might appear at first sight, since the less or greater humidity of the lower strata of the atmosphere depends in great measure on the dryness or the reverse of the upper layers of the soil.

That the specific poison of diphtheria consists of a living organism is now pretty generally recognised, although there is some doubt as to its identity. Klebs first pointed out that there is uniformly present in diphtheritic membranes a bacillus possessing definite morphological characters which he believed to be peculiar to this disease. In addition, there are always present a great variety of micro-organisms, chiefly micrococci, which have no particular significance. Löffler confirmed the frequent presence in diphtheria of this bacillus, and succeeded in isolating and growing it in suitable media, particularly on serum or in agar beef broth. He stated, however, that it was not possible to find it in a number of cases that he examined, but Klein has uniformly found it in all recent cases examined by him; moreover, Klein has isolated the bacillus in cultures and produced therewith diphtheritic disease in lower animals.

Roux and Yersin, recently working at the Pasteur Institute, adopt the Klebs-Löffler bacillus as the essential cause of diphtheria, stating not only that they have been able to transmit the disease to pigeons and rabbits by inoculations of this bacillus, but that the nutrient fluid in which it had been grown, after being passed through a filter of unglazed porcelain, when injected into the subcutaneous tissues of various animals (the required quantity depending on the age of the culture), produced either a rapidly fatal result or a less acute illness with subsequent paralytic symptoms. These investigators found, moreover, that a growth of the bacillus may, if protected from air and light, be kept for an almost indefinite time and still produce characteristic symptoms in animals inoculated with it, but that, exposed to air and light, it speedily loses its virulence. These facts would appear to warrant the supposition that the bacilli may exist, for an indefinite period, dormant in soil, particularly that beneath dwelling-houses, where, protected from light and excess of oxygen, and supplied with a necessary amount of heat, they would regain their full energy as soon as their environment became more favourable. If the pathogenic nature of the Klebs-Löffler bacillus be admitted, it will be obvious that such a state of affairs may have an important bearing in connection with outbreaks of diphtheria where there has been no evidence of importation of the disease from without, but where there is a history of a previous outbreak in the same house, perhaps after a long interval of years.

Cholera

The first and most obvious characteristic of this disease is its preference for particular localities; the conditions which determine its local settlement being, as was shown by Sir John Simon in his Fifth Annual Report (1853), certain demonstrable physical peculiarities which consist in the conjunction of dampness with organic decomposition.

Thus cholera is known to attack with the greatest virulence places of low elevation, especially those which are thickly populated, and which have to contend not only with their local impurity, but also with impurities carried into them by the drainage of ground water from places situated at a higher level. A low level in itself, however, is not sufficient, unless it be combined with a certain density of population, and it would appear that a comparatively high temperature, both of air and soil, is a necessary factor for the epidemic extension of the disease. Dr. Macnamara states that cholera is more rife in low alluvial soils, and that it advances from east to west, or exactly in the direction from the least to the greater recorded falls of rain, and, as a consequence, just in time-relation with the lowness of the ground water, which will be first lowest in eastern districts and last lowest in western districts.

Cholera, which has been known to be endemic in certain parts of India since 1817, first appeared in England in 1831–32. A second great visitation occurred in 1848–49, when the number of fatal attacks amounted to 53,293, in addition to a great increase in the death-rate from diarrhœa. Even at this time the fact became fully recognised that the spread of the epidemic was largely influenced by filth-conditions affecting air, soil, and water. In 1853 and 1854 the disease again appeared in London, the greatest number of deaths in both years being recorded in the summer and autumn months. In these epidemics the water-supply appeared to be the main factor in the propagation of the disease, a point which will be found fully treated of in another section; but, as Dr. Greenhow pointed out in reporting to the General Board of Health, polluted water was by no means the only cause of cholera spread, the mortality having also 'generally borne a direct ratio to the amount of atmospheric contamination;' soil conditions also playing an important part.

In 1865, an outbreak involving some sixty persons occurred in Southampton, whither the disease appeared to have been brought by steam vessels from the East, where the Mecca pilgrims had been decimated by the disease in the previous year. Again the epidemic first definitely appeared here in the months of September and November, although isolated cases had been recorded as early as the middle of July. Other seaports were affected almost simultaneously, and the disease gradually spread, causing eventually the death of 14,378 individuals in England as a whole, of which London accounted for nearly one-third.

In each of these epidemics the number of deaths had gradually decreased, although the total population had largely increased, and since 1866 cholera has never succeeded in obtaining a firm footing in this country; 'a result which is no doubt due to the steady removal from amongst the people of those insanitary conditions which are essential to its epidemic spread, and to the increasing security afforded by those measures of imperial and local sanitary administration, by which it is sought to diminish sickness and mortality from all preventable diseases' (Thorne Thorne).

The incidence of cholera mortality in England during the epidemics of 1849, 1854, and 1866 is shown in the following table:—

Cholera Mortality

Date	England and Wales		London	
	Total deaths	Deaths per 10,000 living	Total deaths	Deaths per 10,000 living
1849	53,293	30	13,565	51
1854	20,097	11	10,684	43
1866	14,378	7	5,548	18

In this country the theory that cholera is mainly spread by means of the drinking-water has received much support, many instances in which this had undoubtedly taken place having been recorded by Dr. Snow and other observers; but it must be remembered that dissemination may come about in other ways: 'excrement-sodden earth, excrement-reeking air, excrement-tainted water; these are for us the causes of cholera.'

In Germany, however, Pettenkofer and other observers have maintained that the diffusion of cholera is mainly due to movements of the soil water, the fundamental proposition being that cholera never prevails epidemically where the soil is impermeable to water, or where the level of the ground water is not liable to fluctuations. According to Pettenkofer the condition of soil with which cholera is most apt to prevail is that which occurs when the ground water, after having attained a higher level than usual, commences again to fall. It is conceivable that an outbreak might be caused in this way by noxious organic material being washed into wells to which it could not ordinarily gain access; or again, it might be due to micro-organisms present in the upper layers of the soil, which had been awakened into activity by the combined influence of heat and moisture, becoming diffused into the atmosphere when the superficial stratum of the earth again became comparatively dry.

As these views have apparently met with but little acceptance in England, it may be worth while to mention a curious fact quoted by Fagge in connection with the East London epidemic of 1866, which appears to be strongly in favour of Pettenkofer's theory. In a school at Limehouse were four hundred pauper children, not one of whom was attacked with cholera or with diarrhœa. Now, the house had its sole water-supply from the Old Ford reservoirs, by which it had been thought the disease was spread, and the children at all times made free use of the water. A special investigation of the soil beneath this school brought to light the fact that it stood upon a thick layer of fine brick-earth, and not of gravel, as appeared to be the case with the streets immediately adjacent.

It should, of course, be remembered that Pettenkofer admits the necessity for the presence of a specific germ, which, however, is only able to assert itself in a virulent manner when its environment is suitable, so that the state of the soil is really a predisposing cause. Nägeli, a supporter of Pettenkofer, further suggests that the soil gives off certain microzymes which must be present in the body of everyone who is to afford favourable conditions for the development of another set of microzymes derived from a pre-existing case of cholera, which would, however, probably be too few to be able to overcome the resistance of the living tissues, unless these latter had first been weakened by the previous invasion of organisms peculiar to the soil.

The researches of Lewis and Cunningham at Calcutta seem to prove that in that place the ground-water level, and, in a less marked degree, the rainfall, bear an inverse relation to the prevalence of the disease. When the latter is at a maximum the water level is at a minimum, and when the water level is at a maximum the prevalence of cholera is at a minimum. There is, however, no correspondence as between one year and another or one month and another; or, in other words, the absolute height of the subsoil water is *by itself* of no significance for the amount of sickness. Still, they call attention to the fact that the two years—1871 and 1872—in their eight years' period, which had the minimum number of cholera cases, were distinguished by the remarkably high level of the subsoil water.

Hirsch makes a great point of the statement that it is always an essential circumstance that the soil be saturated with moisture, but only to that degree

at which it is still pervious to air, and that the organic matters accumulated in it should undergo decomposition, under the influence of somewhat high temperatures. Consequently the question is not as to the extent of the stratum of soil saturated with moisture and permeable to air, or, in other words, a question of the higher or lower level of the subsoil water, but it is a question whether such a stratum exists at all, and that is, in his opinion, the gist of the much quoted and much misunderstood doctrine of Pettenkofer as to the significance of the height and fluctuations of the subsoil water in the production and diffusion of cholera.

This conception of the part played by variations in the amount of water in the soil is indeed upheld by Pettenkofer himself, who, writing in 1870, says: 'In my view, the level of the subsoil water reveals nothing more than this, viz., the limits of a certain degree of humidity in a porous stratum of soil, or the limits within which the pores are kept constantly full of water and all the air driven out of them. Between that degree of humidity and absolute dryness of the porous stratum, there are all those gradations when the pores are filled in part with air and in part with water in varying proportions, which we include altogether under the terms "moist" or "wet." The point at which the pores are completely closed by water, is one that may be observed with ease and certainty, and I have therefore chosen the level of the subsoil water merely as an easily seen gauge and index of certain states of humidity in the stratum of porous and permeable soil which overlies the subsoil water, an index, viz., of the fluctuations in the state of humidity within a given period, and of the time that any one degree has lasted. Whether that index is a few feet nearer to or farther from the surface does not affect the value of its revelations. For the importance of the index lies in this: that it declares the changes in the humidity of the overlying strata, by means of the natural effects of those changes. The fluctuations in the level of the subsoil water have a meaning for ætiology only because they are traced back to those primary influences by which air and water are made to share in varying proportion the possession of the pores of an impregnated soil. Beyond that, they have no significance; . . . looked at by itself and for its own sake, the condition of the subsoil water has as little significance as the hands and dial of a watch dissociated in thought from the works to which they belong.'

Lewis and Cunningham found no such close relation as that between the cholera-curve and the curve of the subsoil water level, in connection with either conditions of soil temperature or amount of carbonic acid, although, in so far as soil moisture appears to determine the amount of carbonic acid in the soil, there was a general coincidence in regard to the latter also. The relations between rainfall and prevalence of cholera, were not so strongly marked as those between the latter and the water level; and it even appeared as though the inverse relation between conditions of water level and prevalence of cholera were in some degree more distinct than the direct one between the water level and the rainfall.

In another place Dr. Cunningham further says: 'One point seems worthy of remark, and that is, that there is no evidence of the existence of any common condition affecting local sources of water supply, and simultaneously affecting the prevalence of cholera and bowel complaints.' And again: 'If the concurrence of a low water level and high prevalence of cholera in Calcutta be more than a mere coincidence—if any causal relation exist between the two phenomena—it cannot be a direct simple one depending on the mere mass of water in the soil,' which, however, bears out Pettenkofer's contention.

Dr. Macnamara and others have asserted that not only is rain connected with the development and dissemination of cholera poison, but that in India no widespread epidemic can occur unless during or after rain. On the other hand, there can be no doubt that the opposite effect is not infrequent, particularly if the rainfall be excessive, prevalence of the disease being prevented by destruction of the micro-organisms, partly as the direct result of the amount of water in the soil, and partly from their being carried further from the surface where they are no longer among surroundings favourable to their continued existence. This fact is well shown in the following table compiled by Dr. Macpherson:—

Table showing Deaths from Cholera in Calcutta for Twenty-six Years

Month	Cholera. Total number of deaths	Rainfall	Average temperature	Range of temperature
		Inches	Fahr.	Fahr.
January	7,150	0·21	63·4°	17·9°
February	9,346	0·42	74·2	17·3
March	14,710	1·13	82·9	16·3
April	19,382	2·40	86·6	14·7
May	13,335	4·29	89·0	13·3
June	6,325	10·10	86·2	9·0
July	3,979	13·90	84·0	6·4
August	3,440	14·40	82·6	5·2
September	3,935	10·40	83·8	6·6
October	6,211	4·72	81·1	8·8
November	8,323	0·90	75·4	14·2
December	8,159	0·13	66·9	16·4

Similarly Fodor has shown at Buda-Pesth that, although a certain amount of moisture of the soil is necessary for the appearance of an epidemic of cholera, yet its spread is immediately checked if there be a considerable fall of rain. Thus, in 1866, not only was the rainfall above the average, but the level of the Danube rose unusually high, and, as a consequence, cholera, which had been prevalent, fell off, notwithstanding that the atmospheric temperature was high. Later on the rainfall diminished, the Danube fell rapidly, and cholera once more asserted itself. In 1873 also, the disease increased in July coincidently with a slight rainfall, reaching its highest point for the year in the following month. In the previous year cholera had not been present, due apparently to the fact that there had been an exceptionally heavy rainfall during the summer and autumn.

At Buda-Pesth the epidemic zone, as it is termed by Fodor, coincides with those parts of the town which lie lowest, there being, according to this observer, an unmistakable connection between the height of the ground level and cholera prevalence. He shows, however, that there are certain streets which have been severely visited at various times, although situated in the higher parts of the town; but the anomaly is apparently due to their being on the border of high ground, below which the surface sinks down suddenly. Pettenkofer observed the same fact in the cholera epidemic of 1854; houses similarly situated suffering as severely as those on a much lower level. Cordes also states that in each of the eleven cholera epidemics which occurred at Quebec between the years 1832 and 1866, the disease was especially prevalent in the same parts of the town, viz.—four different areas which were sunk below the general level; and also that when the disease was introduced into the higher parts of the town it did not spread.

A similar observation is recorded by Günther with regard to an epidemic of cholera which occurred at Dresden in 1873, when a single street was

particularly affected, more than half of the inhabitants of twenty-two houses invaded within a short time of one another having died. In this instance the soil was found to be very polluted at the time of the epidemic, and the drain connected with these houses had apparently been blocked for a considerable time.

With regard further to the vexed question as to whether cholera is most predisposed to by certain conditions of water or soil, although it can be readily understood that the disease may result from the ingestion of water containing the evacuations of cholera patients, it may also be supposed that the use of impure water of any kind may aid the production of the disease, although it cannot absolutely produce it. In this way we may, perhaps, reconcile the conflicting theories, since, as has been shown previously, when the ground water commences to fall after an unusually high rise, it would naturally be preceded by a fall in the wells and other sources of drinking water, and thus the drainage of the upper foul layers of the soil would be carried by the ebbing tide of ground water into such outlets; and so the water supplied to a neighbouring population would become dangerously contaminated, and the more so the fouler the surface layers of the soil. The facts which will be found quoted in another section on the influence of the Lambeth water during the epidemic of 1854 seem to support this view, and we have further evidence in favour of it derived from the investigation of later outbreaks in Germany. The water may act in this way: either by causing a constant tendency to diarrhœa, a disease which is for the most part exceedingly prevalent, both antecedent to, and concomitantly with, cholera epidemics, or by carrying into the alimentary canal organic matter of an injurious nature. This either affords a fitting pabulum for the *materies morbi* of cholera when brought into contact with it, or else may undergo special chemical changes under the influence of small doses of the cholera microbe as may convert it into a still more virulent poison; or, again, by lowering the normal powers of resistance of the body, may render it an easier prey, not only to cholera, but to disease in many other forms as well.

The 'Comma' Bacillus

The researches of Koch, when working on the German Cholera Commission, have rendered it highly probable that a particular micro-organism, termed the 'comma bacillus,' is always associated with Asiatic cholera. He has found it not only in the alvine discharges of patients suffering from the disease, but also in the soil and in the water-tanks of infected districts. Nearly fifty years previously Pacini had described 'vibrios' as being present in the intestinal discharges of cholera patients, but whether these bodies were identical with Koch's bacillus is uncertain.

The specific micro-organisms called 'comma bacilli,' on account of their shape, are to be found during the acute stage of cholera in the rice-water discharge from the intestines, and consist of little curved rods of about the thickness of a tubercle bacillus, but only half its length. They are actively motile, and multiply by fission, often producing during the process S-shaped or spiral forms from the progeny of an individual bacillus remaining in contact with one another.

As to this bacillus, Macleod and Milles describe the following characteristic points: 'It grows in and liquefies slightly alkaline gelatine; more slowly in neutral, scarcely at all in slightly, and not at all in markedly acid gelatine. On a gelatine plate cultivation the individual colonies are round, and lie in a funnel-shaped cavity; when viewed with transmitted light and magnified, they look like ground glass, and the edge of the colony is finely

notched. In a gelatine tube a funnel-shaped cavity forms at the top of the puncture made by the inoculating wire, and lying in this cavity there is what looks like an inverted air-bubble with its top on a level with the surface of the jelly and open to the air; along the puncture the gelatine liquefies, and in this may be seen with the naked eye the whitish mass of colonies, particularly at the lowest part; in from three to four weeks liquefaction spreads to the whole mass, the bacilli falling to the bottom as a greyish-white sediment, having a faint orange tint in certain lights, and if undisturbed a perfectly transparent liquid separates a whitish scum on the top from the sediment below.' Like most other pathogenic organisms, it grows best at about the body temperature, any considerable range below or above this inhibiting the growth, although the bacillus is not destroyed if the temperature be reduced to the freezing point. It is aërobic, as if air be excluded growth ceases; while it is killed altogether by drying, as apparently spore formation does not take place.

Klein, however, on repeating Koch's experiments, has been unable to confirm them, and consequently denies the pathogenic importance of the comma bacillus. It has been shown that a similar organism is to be found under normal circumstances in the mouth, and Klein believes its presence in the intestine to be merely accidental, the large numbers which he allows are always to be found in cholera dejecta being due, in his opinion, to the state of the alimentary canal being favourable to their multiplication.

Great stress has also been laid on the ease with which the vitality of the comma bacillus is destroyed, as affording an argument against the likelihood of its being the medium of infection. Not only are they killed by drying, but also by the addition of small quantities of acid, so that they may be given by the mouth in the case of the guinea-pig without the animal being affected, as the acidity of its gastric juice is sufficient to destroy them. In order to obviate such an event when experimenting on the possibility of producing the disease in the guinea-pig, Koch injected soda solution into the stomach, and thus in some instances enabled the bacilli to reach the duodenum uninjured by the secretion of the stomach. Weak disinfectants and the presence of putrefactive organisms are also inimical to the comma bacillus, Cunningham having shown, for instance, that if a portion of a cultivation of commas was inoculated into water or soil, the length of time during which they could still be recognised in the living state depended directly on the amount of pollution of the medium into which they were sown. Thus in one series of experiments, when water polluted with excreta was used, it was found that all the bacilli had disappeared in a period varying from four to nine days, while if the water had previously been sterilised by boiling, they were found as late as the twenty-fifth day. Kitasato has apparently established the same fact with regard to the action on the bacilli of the micro-organisms present in fæces.

From these experiments it would appear that cholera dejecta, when buried in the soil or thrown into water, would be likely to be rendered innocuous within a comparatively short time, but in this connection an instance of infection by water described by Macnamara is worthy of attention. He states that 'a small quantity of the dejecta of a cholera patient was known to have been washed into a vessel containing water; the mixture, after being exposed to the heat of the sun for one day, was swallowed by nineteen men on the following morning; within three days five of these were affected with cholera.'

Nicati and Rietsch have also shown that cholera bacilli are capable of existing for as long as eighty-one days in the water at the port of Marseilles, so that it is possible there may have been some source of fallacy in Cunningham's experiments.

Moreover, these observers found that a disease very similar to, if not identical with cholera, could be induced in guinea-pigs by the injection of comma bacilli into the small intestine. Koch, as has been said, improved on these experiments by giving the culture by the mouth, mixed in sufficient of an alkaline solution to prevent the destructive action of the gastric juice, and at the same time inhibiting peristalsis by the use of tincture of opium. 'Experiments were made on thirty-five guinea-pigs; of these, thirty died of cholera. The symptoms during life and the appearances after death were identical with those found in guinea-pigs which had received duodenal injections.'

The results thus obtained by Koch have been fully confirmed by Macleod and Milles, who come to the conclusions that the comma bacillus is invariably present in cases of Asiatic cholera, although there is no evidence to show that it is a normal inhabitant of the human alimentary canal; that when introduced into the small intestine of the guinea-pig in the manner and with the precautions already mentioned, the organism multiplies in the alimentary canal, and that associated with such growth changes are found similar to those which are known to occur in Asiatic cholera when the human being is attacked.

From a review of all the evidence brought forward by the supporters and antagonists of Koch's views respectively, it may fairly be stated that the balance of scientific opinion is distinctly in favour of the pathogenic nature of the comma bacillus. Finkler and Prior, indeed, have described another bacillus found by them in cases of cholera nostras, which, however, is not only readily distinguished from Koch's bacillus by the manner of its growth in various nutrient media, but which is probably never present in cases of true cholera.

In the light of what has been stated with regard to the ætiology of the disease, the prophylactic measures to be taken against the invasion of cholera obviously comprise such as will prevent its admission into a community, or hinder its spread if it be introduced from without; it being also of great importance to reduce if possible the individual susceptibility to attack.

In this country confidence is no longer placed in a system of quarantine for the prevention of cholera, scientists being now for the most part of opinion that it is not only easier, but far more effective, to provide against the development of cholera by such improvements in general sanitation as will render it difficult for the disease to obtain a footing. Pettenkofer has well expressed the contrast between the efficiency of quarantine and local sanitation as safeguards against cholera in comparing an epidemic to the explosion of a powder magazine. The powder represents the local conditions predisposing to an outbreak, while the virus of cholera is the spark which can evade the strictest quarantine. 'It is wiser, therefore, to seek out and remove the powder than to run after and try to extinguish each individual spark before it drops upon a mass of powder, and, igniting it, causes an explosion which blows us into the air with our extinguishers in our hands.'

It is specially necessary to guard against pollution of the soil, since such a state of things means in all probability contamination also of water and of air, all of which conditions will certainly encourage the incursions of the disease. Moreover, since it has been definitely proved that the discharges from the stomach and intestines contain the active agents for propagation of the disease, and that at the same time the bacilli are more easily destroyed when first carried out of the body, the immediate disinfection of all such discharges must be carried out by some efficient substance, such as corrosive sublimate or carbolic acid, which Koch has shown is capable of killing the comma bacilli when diluted to the extent of one part in fifty with water.

Malaria

In spite of the wide distribution of malarial fevers, of their disastrous effects upon the population of countries in which they prevail, and of the vast extent of the literature of the subject, we are unfortunately almost as far as ever from an exact understanding of the precise conditions necessary for their existence or production. There is, however, a general consensus of opinion that malaria most abounds in jungle, swamps, and virgin forests, the disease showing an evident relation to low land, abundant water, and hot moist climates, and North has called attention to the fact that if a physical map of Italy be compared with the map of Signor Torelli showing the local distribution of malaria, such relation of the disease to water temperature and altitude of the land becomes well-nigh a certainty. In the province of Rome the disease is found to be generally most severe on low-lying ground in valleys and in marshy districts; there, curiously enough, the distribution of the population is the reverse of that which usually obtains, for whereas in most civilised countries the population is densest in the plains and much more sparse on the mountains, in the province of Rome exactly the opposite state of things holds good, the mountain population being nearly $2\frac{1}{2}$ times as numerous per square kilometre as the dwellers in the plains. It was this curious reversal of the general rule that caused North to carefully investigate the matter with the object of determining, if possible, whether it was malaria which in the first instance compelled the inhabitants of the plains to take refuge on the hills, or, on the other hand, whether having been driven thither from political causes, malaria had stepped in subsequent to the abandonment of the plains, and in either case where and when such causes first came into operation. He comes to the conclusion that the Campagna was abandoned from causes purely political, Nature being then allowed her own way in a country where the unceasing toil of man is required to keep her under control. In even the later days of the Roman Empire, places now absolutely uninhabitable were not only inhabited, but held in high esteem by the Romans as health resorts, so much so that the whole coast-line of the province was covered with their villas and country houses, of which the ruins still exist, and which Pliny states to have been maintained in a state of magnificence incompatible with the presence of such an enemy to health as malaria. There is some evidence, however, that the Pontine district was not all that could be desired even in those times, Seneca advising a friend to avoid the neighbourhood of Ardea as not being very healthy. The invasions of the Goths swept away these villas, with the gardens, the sacred groves, and the high cultivation that surrounded them, the population being driven to secure places in the hills. In the seventh and eighth centuries widespread outbreaks of fever occurred, and serious attempts were made by various Popes, with, however, but slight success, to recolonise and cultivate the desolate country. There can be no doubt but that the reckless destruction of trees, which has gone on steadily ever since it was begun by the Goths, has played a most important part in altering the local conditions and local climate of the country; and in comparatively recent times the destruction of timber in the mountains has caused the streams which rise in them to become uncontrollable and destructive, converting large areas of low land into bog and swamp, and rendering cultivation difficult and unprofitable.

A moist soil, particularly if uncultivated, is then an important factor in the causation of malaria, particularly when associated with it there is a high soil temperature (about 65° Fahr.) and impurity of ground air and of soil,

the latter being usually of vegetable origin. The rise or fall of ground water, by causing variations in the amount of moisture present, evidently plays an important part in producing or controlling periodical outbreaks of paroxysmal fevers in countries which are liable to malaria. The development of malaria may be coincident with either a rise or a fall of the subsoil water, although Fodor found that, with an increased height of the ground water, malaria died away, while as the soil became drier it again put in an appearance. Thus, in 1887, at Buda-Pesth the soil was driest in the summer and autumn, and it was just at this period of the year that the malaria curve rose highest, a great increase of malaria following on the sinking of the moisture curve relating to a depth of one metre below the surface. Afterwards the amount of moisture increased till the middle of September, and malaria fell off from the middle of September to the middle of October, Fodor considering that the difference in time was accounted for by the incubation period of the disease.

Rainfall, on the other hand, appears to bear a direct relationship to the disease, the malaria curve generally falling during the fall of rain, while during dry weather the curve at once commences to rise. If, however, the malaria curve be compared with the changes going on in the deeper parts of the soil, such as the range of moisture or the fluctuations in the amount of carbon dioxide (and so with fluctuations in the amount of putrefaction going on in the soil), no such connection can be traced. While, however, on the other hand, there is an evident relation between the extent of malarious disease and the amount of moisture in the upper layers of the soil and that of the rainfall, the influence is drawn that the malarial miasma is produced in the most superficial layers of the earth and is independent of decomposition changes in the deeper portions of the soil, thus contrasting markedly with certain other diseases.

The temperature of the atmosphere also exerts a considerable influence on the prevalence of malaria, which has been carefully worked out by Fodor, who found that a continuance of high temperature for a few days, at any time of the year, was regularly followed in about a fortnight or three weeks by an increase in the number of cases of malaria. A low temperature, however, may not always check the spread of malaria, when other favouring causes are present. The rise of the malaria curve did not immediately follow the rise of summer heat, a certain degree of warmth being apparently needed for the ripening of the germ; but curiously enough Fodor found that in spring a relatively small amount of warmth sufficed to bring about an increase of malaria, his experience on this point being, moreover, supported by other observers. Laboratory experiments also appeared to prove that winter frost, or winter rest, must have some special influence which disposes the germ to develop promptly with a rise of temperature in spring, while later in the year it needs more warmth, and a more prolonged period of such warmth.

The escape of the miasm of malaria into the air is probably not so much due to the effect of currents of atmospheric air aspirating the soil as to the movements of the ground air caused by differences of density. Thus the ground air tends to rise into the atmosphere more particularly towards the evening by reason of its rarity as compared with that of the air above, and it is in the evening and at night in summer and autumn, when the atmosphere is generally polluted with ground air, that malarial infection most often occurs, while by day, when there might be supposed to be more exposure to malarial emanations, infection rarely occurs. Hence also the germ cannot be present in the dust at the surface of the earth, but rather contained by the ground air

below the surface. Confirmation of this is found in the fact that in malarious regions the digging up of the soil has frequently caused an epidemic of malaria among those employed in the work of excavation.

Obstructions to the outflow of the ground water in malarious soils, as occurred during the construction of the Ganges and the Jumna Canals, in which the outflow of a large tract of country was impeded, have often been followed by widespread malarial epidemics. Both in India and in the United States it has also been noticed that obstruction to the natural drainage caused by the blocking of watercourses by mills and dams has been, at any rate in part, the cause of severe and fatal outbreaks of the disease. A rapid rise in the ground-water level may follow on an exceptional rainfall, particularly if the outfall, though sufficient in comparatively dry weather, is inadequate for carrying off an amount of water much in excess of the usual amount. Such an instance occurred at Kurrachee, in Scinde, where the ground is flat and there is no subsoil drainage, but where, as the rainfall is usually small, and the ground dries fast, an epidemic of malaria is an event almost unknown. An unprecedented fall of rain in 1869 was, however, followed by so widespread an outbreak, that the regiment which was stationed there at the time had to be embarked for Madras, as every man had been attacked, although fortunately the disease had not been present in a very fatal form.

Conversely the lowering of the subsoil water due to an increased outflow, the result of extensive drainage operations, has in many places brought about a remarkable reduction of malarial disease. This has been especially noticeable in England, in the counties of Norfolk and Lincolnshire, which within comparatively recent times were noted haunts of malaria, but where, at the present day, owing to the reclaiming by systematic drainage of large areas of marshy country, the disease has practically disappeared.

Pettenkofer relates a case which is of interest as showing the effect of subsoil drainage on a form of fever allied to malaria occurring among horses in the royal stables at Munich. Although the sanitary arrangements in each of the two stables appeared to be equally good, and the food, accommodation, and attendance in each were apparently similar, horses suffered much more severely in one than in the other. The disease was not infectious, as horses removed from the unhealthy stable did not communicate the disease to those in the more healthy one. After careful investigation, the only circumstance that could be found to account for the difference between the two places was that whereas in the case of the healthy stable the ground water was met with at a depth of between 5 and 6 feet, at the site of the unhealthy stable it rose to within $2\frac{1}{2}$ feet of the surface. Deep drainage was then resorted to in the latter situation, and, the level of the ground water having been reduced to the same point as at the healthy site, the disease disappeared.

Malarious Soils

The soil in districts in which malarial fevers are prevalent is usually more or less marshy, or, at any rate, is in the vicinity of extensive marshes, although there are occasional exceptions to this rule. In addition to being saturated with moisture, such soils also contain a large amount of decaying vegetable matter, and the air above may hold large amounts of carbonic acid, marsh gas (light carburetted hydrogen), sulphuretted hydrogen, and watery vapour, while suspended in it may be found *débris* of vegetable and animal organic substances, diatoms, infusoriæ, algæ, and various micro-organisms. These, which are all in the first instance derived from the soil, doubtless include the particular agent to which the propagation of the disease is due,

but it is quite possible that other of the constituents of air or soil may, by their effect on the system, predispose to the attack of the malarial organism. Thus it has been supposed that the sulphuretted hydrogen which is evolved in great quantities from marshes in certain districts, may give rise to symptoms of anæmia and prostration, which not unfrequently accompany malarial poisoning. As to the exact chemical conditions of soil which favour the production of malaria, but little is at present known, as exact chemical estimations have not been systematically carried out, but there can be little doubt that the inorganic constituents of the soil have little or nothing to do with the problem, since in different parts of the world malaria is found to prevail on soils which range from the most impervious forms, such as even granite, to the loosest forms of sand.

The large amount of vegetable matter found in some malarial soils, amounting to about 30 per cent. in the case of the Tuscan Maremma, and possibly even more in other districts, gives rise, during putrefaction, to various organic acids, named humic, ulmic, crenic, and apocrenic, of the exact chemical constitution of which there is at present but little known, and it may be that these may exert a deleterious influence on health, either by being carried by air or water. In some cases the process of decomposition of the vegetable forms is one which extends over an almost unlimited time, plants having been found still undestroyed in marshy districts where the same conditions have prevailed for centuries.

The influence of vegetable decomposition in helping to give rise to attacks of ague is well seen in an instance quoted by Friedel. He mentions that in the Marine Hospital at Swinemünde, near Stettin, patients who were placed in a certain convalescent ward invariably contracted a bad attack of tertian ague after a residence there of two or three days. No cases occurred in any of the other wards, and the curious incidence of the disease leading to a thorough investigation, it was found that outside the windows of the affected ward was a large rain-water cask full of rotten leaves and brushwood. Water had overflowed from the cask and formed a large stagnant pool alongside the ward into which effluvia had freely found their way, particularly when in the hot weather all doors and windows were kept open at night. This state of affairs having been attended to, the ward in course of time lost its evil reputation. It is not, of course, suggested that vegetable effluvium is of itself sufficient to cause an attack of malaria, but evidently there were present in this instance circumstances which would be exceptionally favourable for the development of the particular organism immediately concerned.

On the other hand, ague of a most virulent form has been met with in districts which appeared to be perfectly dry and arid, thus showing that the presence of decomposing vegetable matters is not essential. Thus, according to Hirsch, the tableland of Castile, the plain of the Araxes, and the lofty plateaux of Northern India and Persia are all highly malarial, and even in Italy careful inquiry has apparently proved that some malarial districts are in considerable part devoid of water and sterile. We have it also on the authority of Dr. William Ferguson, nearly a century ago, that he had observed instances in which British troops were attacked with the disease while encamped upon dry sandy soils, both in Holland and in Spain. Friedel and Maclean have laid stress on the development of malaria in Hong Kong and other places situated on hard rock (*granitic* and *metamorphic*), particularly where these have become weathered and disintegrated, but in such districts it is quite possible that it is not dependent so much on the actual disintegration of the granite as upon the abundant cryptogamic vegetation which is found in the soil filling up the clefts in the rock. In many instances also in

which malaria has shown itself in places where the soil was apparently free from moisture, water may have been present, even in considerable quantity in the lower layers of the soil, especially where a substratum of clay or other impermeable material existed, the soil being only saturated up to a certain level.

Although malarious diseases are doubtless most prevalent in the neighbourhood of marshes, these may exist even over considerable areas without paludal fevers making their appearance. This is notably the case in countries like Ireland, which are widely covered with peat bogs, but where malaria is not at all abundant. Moreover, marshes which are regularly overflowed by salt water do not breed the disease, notwithstanding that their surface is exposed for a large part of each day. Even in marshes not exposed to the action of the sea, investigations have shown that malaria is often not developed during the wet part of the year, when the ground is entirely flooded with water, but rather during those seasons at which large parts of it are exposed to the air and so become more or less dry. On the other hand, in Italy it has been noticed that occasionally the overflowing of fresh-water marshes by the sea has caused a considerable development of malaria, but obviously the conditions are different to those which obtain in the case of a daily flushing by the tide.

Many alluvial soils, particularly those which have been recently formed, give out malaria, even though they may not be marshy. This may be due to the fact that they contain more organic matter, which would be especially likely to be the case where they occur in the vicinity of streams, as along the estuaries and deltas of rivers which are for the most part only occasionally covered with water. In all such situations, however, the malarial poison is strictly localised, the interposition of a belt of trees or of a sheet of water being sufficient to protect the inhabitants of neighbouring districts from its influence. Thus, when English troops occupied Walcheren and other parts of Holland, it was several times noticed that only those soldiers who disembarked were attacked by ague, those who remained on board ship, even when in narrow channels, escaping.

Certain sandy soils, especially when impregnated with a large proportion of iron, have been reputed to be extremely malarious, but the influence of the iron in this connection is more than doubtful, the supposed effect having more probably to be sought in the presence of organic matters, which are often found in large amount, as in the sandy soil of the Landes, in south-west France.

The Bacillus and Plasmodium Malariæ

From the evidence that has been brought forward, it appears certain that there is a very close relation between certain soil conditions and the occurrence of malarial disease, and consequently numerous observers have sought for the presence in malarious soils of some organism which might possess the power of transmitting the disease. Klebs and Tommasi-Crudeli, while engaged on such a series of experiments, found in the soil of the Roman Campagna a distinctive bacillus which they believe to be the specific cause of malaria. The bacillus, which varies considerably in size, up to the diameter of a red corpuscle of the blood, grows in artificial cultures into twisted threads; inoculated into rabbits it is stated to produce a febrile disorder analogous to malarial fever, while threads and spores may be found in abundance in the spleen and marrow. Marchiafava has described bacilli with end-spores as occurring in the blood of patients suffering from malaria.

The latter observer, however, in connection with Celli, has more recently found that peculiar amœboid bodies (plasmodia), occasionally showing motile filaments, and often containing granules and black pigment masses, are constantly to be found in the blood in cases of malaria, either free or enclosed within the red corpuscles. These organisms are probably allied to the flagellated protozoa.

Although general interest in this subject was perhaps first roused by the publications of Marchiafava and Celli, who gave the name *Plasmodium malariæ* to the organism they found in the blood, it had been previously described by Laveran in Algiers in papers communicated by him to the Paris Academy of Medicine in 1881 and 1882, his researches being finally embodied in a large work which he published on the malarial fevers. He found as characteristic elements in the blood of persons attacked with malaria, (1) crescentic pigmented bodies, (2) pigmented bodies in the interior of red corpuscles, which underwent changes in form, described as amœboid, and (3) a pigmented flagellate organism. He looked upon all these forms as phases in the development of an infusorial organism which he regarded as the germ of the disease. These observations have subsequently been for the most part confirmed by Richards, Councilman, and Osler.

Mosso, however, has sought to prove that these bodies resolve themselves into degenerative types of the red blood-corpuscles, in which he is supported by Tommasi-Crudeli, who regards the forms in question as the result rather than the cause of malarial disease, and who, moreover, still maintains the pathogenic nature of the bacillus discovered by Klebs and himself. Von Taksch states that he has many times examined the blood of patients suffering from intermittent fever, without ever finding such bodies as those described by Marchiafava, Celli, and others; but against such merely negative results may be placed the experience of Osler, who examined seventy cases of this disease, in not one of whom did he fail to find the plasmodium. It would appear from his researches, however, that the organisms concerned assume a greater variety of forms than was previously supposed, which may possibly account for them having been overlooked in some instances.

Yet another organism has been described by Sakharoff as being present in the blood of malarial patients. This parasite, which may attain enormous proportions, as large as twenty corpuscles together or even larger, consists of a mass of extremely fine protoplasm containing numerous dark roundish sharp-coloured motile granules and a greyish nucleus about the size of two blood-corpuscles. The hæmatozoön is capable of transformation into a number of bright homogeneous clear bodies, which are formed by the separating off of protoplasmic processes. In course of time some of them penetrate into the red corpuscles, increase in size, develop pigment granules, and gradually pass into the adult form mentioned above; while other bodies having a smaller size coalesce to form threads closely resembling the spirochetæ of relapsing fever, differing only from the latter in their being somewhat thicker, and in their performing comparatively slower, wave-like movements. The intracorpuscular form he believes to be identical with Laveran's malarial parasite.

It will be seen from so many contradictory statements that the question as to what is the specific cause of intermittent fever is not yet satisfactorily solved. Even supposing that these amœboid forms are invariably present, the question arises, Are they pathogenic or are they merely associated with the disease, which in some way furnishes conditions favourable to their growth? As evidence of their pathogenic nature may be urged the constancy of their presence, their absence from other healthy individuals in malarial regions,

their destructive influence on the blood-corpuscles, and their abundance in many of the graver forms of the disease. So far the presence of these bodies has not been demonstrated in soil, nor have they yet been cultivated outside the human system, but by inoculation and the intravenous injection of malarial blood containing them, Marchiafava and Celli have succeeded in communicating the disease to other individuals; but in regions where malaria is prevalent such experiments cannot but be looked upon with suspicion. It should, however, be remembered that hæmatozoa are not uncommon in animals, and as in the rat do not appear to interfere seriously with the health of their host. Under these circumstances the association of a specific form with a definite disease in an animal makes it all the more probable that the species is pathogenic (Osler).

Golgi has, moreover, recently attempted to prove that the paroxysms of intermittent fevers bear a direct relation to the development of generations of parasites, and that the different developmental periods of different broods are the conditions determining the varying periodicities of the recognised varieties of malaria. He claims that the experienced observer can distinguish by biological and morphological characteristics those organisms which have a life-cycle corresponding with the periodicity of tertian ague from those in which the cycle corresponds with the quartan variety of malarial fever. The endoglobular amœboid bodies found in tertian fever show much more active movements than those of the quartan form, in which latter these amœboid changes can only be distinctly observed in the first stage of their development, and never very readily, it being usually necessary to warm the preparation in order to excite them. In quartan fever the affected corpuscles are stated to become shrunken, but to retain their colour in great degree up to the latest phase in their destruction; while in tertian fever, on the other hand, the parasite which completes its developmental cycle in two days, as opposed to three days in the quartan form, decolourises in an energetic and rapid manner the red blood-corpuscles, which, however, retain their regular outline, appearing in some cases even larger than normal. Finally, the author relates a case, the obscure clinical features of which were explained by his discovery in the blood of the organisms peculiar to both quartan and tertian fever, those of the former variety being most numerous.

Should further research confirm these observations, there can no longer be any doubt that these parasitic organisms play a most important part in the ætiology of malarial fevers, and seeing that, even at the present time, such connection appears, to say the least, more than probable, it is highly desirable that attention should be turned to the more thorough understanding of the life-history of the *Plasmodium malariæ* and particularly to the question as to whether, under certain conditions, it is capable of living and perhaps of multiplying in the soil of districts favourable to the development of the disease, and also to those circumstances which either encourage or are inimical to its development in the body. Pending more exact knowledge, however, in this drection, there remain other factors in the causation of malaria which must not be lost sight of, as by due attention to them much may be done in preventing the appearance or diminishing the virulence of the disease.

Among such preventive measures must be mentioned thorough and deep drainage, by which the subsoil water is permanently lowered and stagnant sheets of water caused to disappear. The nature of the soil also should be inquired into, and if found to contain much organic matter houses built upon it should be protected by a layer of concrete underneath, to prevent the upward passage of the ground air; while even greater security in this direction may be obtained by raising buildings off the ground on a series of arches.

Malarial effluvium being most dangerous at night, it is well also that the sleeping rooms should be placed at the upper part of houses, as it does not appear to rise beyond a certain height from the ground. Seeing that the presence of much vegetable *débris* either in the soil or upon it, especially when accompanied by a certain amount of moisture and a warm temperature, tends to favour the development of the malarial agent, it is of importance to remove all masses of decaying vegetation and at the same time prevent putrefactive changes of the soil by providing an outlet for the water, either as already suggested by efficient drainage, or by the planting of trees, which by means of their leaves throw off enormous quantities of water in the course of the day. This is specially the case with the *Eucalyptus globulus*, which is supposed to be capable of absorbing and evaporating eleven times the rainfall over the area it covers. Next in value from this point of view comes the oak; so that it is highly desirable that one or the other of these trees should be planted freely in malarious districts. Where this has been already done, considerable effect in the direction of rendering the locality more healthy has been observed, as when moisture is removed from the soil the malarial organism no longer finds its surroundings favourable for development. Sunflower plants have a similar effect, but of course in less degree. Occasionally great benefit has been derived from covering the ground with grass, which hinders the ascent of the miasma and at the same time causes the evaporation of a considerable amount of soil moisture.

Although trees are valuable both by aiding removal of water from the soil and also apparently from opposing a barrier to the progress of malaria, the same cannot be said of thick undergrowths of brushwood, which only hinder a proper circulation of air, and at the same time favour extensive decomposition. A remarkable instance of this is seen in the case of a large area of *macchia* which lay between the town of Cisterna and the Pontine Marshes. In 1714 it was proposed to cut it down, but this was successfully opposed by Lancisi, the Papal sanitary adviser at the time, on the ground that a barrier or filter was thus opposed to the malarial emanations from the Pontine Marshes. Cisterna at that time was extremely unhealthy, and had a rapidly diminishing population; but when, about one hundred years after, these woods were cut down, the health of the place at once commenced to improve, and the population increased by rapid strides.

There is at present little or no evidence to prove that malaria can be caused by drinking-water alone, since, as North has well shown, 'the healthiest parts of the city of Rome are supplied by water admittedly the best in the world, and which rises—to take the Acqua di Trevi or Acqua Vergine as an example—on unenclosed land, in springs which bubble up and cover the surface in a locality so unhealthy that to pass several nights there in August might involve risk to life, and certainly to health. There seems to be but little doubt that a supply of good drinking-water is of importance in malarious localities, but it has yet to be shown that in exchanging pond and ditch water for that of springs the inhabitants cease to take a poison into their bodies. The evidence points rather to the fact that by so doing they raise their general health, and so become less liable to the disease. At all events, proof that the malarial infection can be conveyed by water is wanting, though very largely credited by the natives of countries where the disease prevails.' At the same time, surface water particularly should be looked upon with suspicion for drinking purposes, and if only shallow wells are available for the necessary supply, it is well that it should be boiled before being taken into the system.

Finally, we possess in quinine a drug which exhibits a remarkable pro-

perty in enabling the body to withstand malarial attacks, and it is therefore only prudent to make constant use of it if residence in or passage through countries where the disease is prevalent be unavoidable.

Rheumatism and Neuralgia

It is probably only in so far as the climate of a locality may be affected by peculiarities of the soil, such as elevation, configuration, the kind of rock, and the physical characters, that we have to take this factor into account in the ætiology of rheumatism. Thus it is well known that the disease evinces a preference for open basins and plateaux exposed to the wind, for damp and deeply cleft valleys, and for sea-coasts or the shores of great rivers.

Dampness of soil may, however, predispose to this disease, from the fact that it renders it cold; and this will be the more likely to be the case at low elevations, and where there is an impermeable subsoil such as clay; but no sweeping assertion can be made on this point, as the necessary data for the institution of the comparative frequency of the disease on different kinds of soil are unfortunately wanting.

Neuralgia, like rheumatism, is doubtless most often the outcome of a constitutional state dependent on influences from without, and ultimately traceable to the circumstances of the locality or of the season, including climate, weather, and soil; but our knowledge of the geographical distribution of the neuralgias is too defective to let us decide with certainty how far influences of the latter kind may determine the prevalence of the malady at various parts of the world (Hirsch). It is noteworthy, however, that Valleia has shown that neuralgias of the rheumatic kind are, along with other rheumatic disorders, commonest within the temperate zone in the cold and wet seasons of the year, while in tropical countries they reach their maximum when the rains begin, and again when they cease. Foltz, Lidell, and Gibson have also called attention to the fact that those states of soil which are favourable to malaria may also predispose to neuralgia, while Hirsch states that Egypt and New Caledonia, which are remarkable for their relative or absolute immunity from malarial fevers and for the steadiness of their climate and weather, are strikingly free from this disease.

Phthisis

Tuberculosis, or phthisis, is a micro-parasitic and possibly infectious disease, which has been proved to have an intimate relation to dampness of soil. It causes an average of 50,000 deaths annually in England at the present time, or more nearly 70,000 per annum, if there be included with it deaths registered as occurring from tabes mesenterica, tubercular meningitis, and 'other forms of tubercular disease and scrofula.'

In presenting his report for 1858 to the President of the General Board of Health, Mr. Simon, referring to a report by Dr. Greenhow on the prevention of pulmonary phthisis, stated that 'pulmonary affections, including phthisis, cause very nearly a quarter of the annual mortality of England. Every 100,000 of our population yields on an average 552 annual victims to this deadly class of disorder.' He also expressed the opinion that pulmonary phthisis then killed, as now, on an average more than 50,000 persons annually in this country; so that, although the total population has enormously increased since that time, the number of deaths has remained stationary. This improvement is shown in another and better manner by comparing mortality statistics in relation to death-rate per unit of population, as in the following table extracted from the Registrar-General's Forty-

fifth Annual Report, which shows the annual mortality per million from 'phthisis' at all ages, and at certain typical ages in both sexes the last three decennia:—

Phthisis in England and Wales

Years	All ages	15—	20—	25—	35—
1851–60	2,679	2,961	4,181	4,317	4,091
1861–70	2,475	2,651	3,928	4,243	4,026
1871–80	2,116	2,036	3,117	3,619	3,745

As a result of his investigation Dr. Greenhow showed, among other things, that 'in proportion as the male and female populations are severally attracted to indoor branches of industry, in such proportion, other things being equal, their respective death-rates are increased,' the evil effect of certain industries, of faulty ventilation, and of overcrowding being also shown to exert a considerable influence in inducing the disease. Notwithstanding such deleterious influences, however, the decrease in the phthisis death-rate has been fairly continuous, so that some other factor must have come into play within comparatively recent years.

It was, however, reserved for Dr. Buchanan to bring to light a most important and unexpected factor in the ætiology of this disease, which goes far to explain the reduction in the death-rate spoken of above. In 1865–66 he undertook an inquiry, the object of which was to ascertain what had been the results obtained by local authorities, who by means of such works as water supply and sewerage had attempted to improve the sanitary condition of the districts under their control. One main purpose of the inquiry was 'that the then Central Public Health Authority should fulfil one of the principal duties expected of it by making new local experiences conducive to general enlightenment;' and this object was, in one important respect, attained in a direction which is best shown in the *résumé* of the subject given by Mr. Simon in his Annual Report for 1866. He there says: 'These columns,' referring to Dr. Buchanan's report, 'appear to indicate a partial dependence of pulmonary phthisis on some of the unwholesome conditions which have been removed. And when detailed examination is made of the cases which give that indication, and they are compared with the different class where phthisis has not lessened its amount, the novel and most important conclusion suggests itself that the *drying of soil which has in most cases accompanied the laying of main sewers in the improved towns has led to the diminution, more or less considerable, of phthisis.* The facts which are yet in evidence seem most strongly to support this conclusion, which, should it be substantiated, will constitute a very valuable discovery evolved by Dr. Buchanan from the inquiries here reported on. . . . It will be seen that the reduction of phthisis where certain works have been executed is far too large and far too general to be regarded as an accidental coincidence. The reduction, namely, on the death-rates by phthisis in the first fifteen towns in Dr. Buchanan's table are as follows: Salisbury, 49 per cent. of its previous rate; Ely, 47 per cent.; Rugby, 43; Banbury, 41; Worthing, 36; Macclesfield, 31; Leicester, 32; Newport, 32; Cheltenham, 26; Bristol, 22; Dover, 20; Warwick, 19; Croydon, 17; Cardiff, 17; Merthyr, 11. And the fact that in some of these cases the diminished fatality of phthisis is by far the largest amendment, if not the only one, which has taken place in the local health becomes extremely interesting and significant when the circumstance is remembered that works of sewerage, by which the drying of the soil is

effected, must always of necessity precede, and do indeed sometimes precede by years, the accomplishment of other objects (house-drainage, abolition of cesspools, and so forth) on which the cessation of various other diseases is dependent. Thus, as regards the two largest populations concerned in this question—those of Bristol and Leicester—no doubt the comparative smallness of effect hitherto produced on the general and diarrhœal death-rates of these towns may (so far as it is not fallacious) be referred to the shortness of time for which finished constructions have been at work for the detailed dispollution of houses and their dependencies; but a reduction already of a sixth in the phthisis mortality of Bristol and a reduction of a fourth in the phthisis mortality of Leicester are apparently connected with the fact that in both towns main sewerage on a large scale, with more or less drying of soil, has existed in comparison for many years. And Rugby, which, long as it has been at work, has not yet succeeded in getting rid of endemic diarrhœa and typhoid fever, shows at least this result of its main drainage works, that its phthisis mortality has fallen 43 per cent.'

In his report for the following year, 1867, Mr. Simon adds: 'The above facts, though not enough in themselves to prove as certain the very important ætiological relation which they suggested, were at least amply sufficient to show that a very promising line of inquiry had been opened.' In consequence of the vast importance of the subject, Dr. Buchanan had continued his investigation, and given the results at which he had arrived in a report, presenting an elaborate examination of the distribution of phthisis, as compared with variations of soil, in the three south-eastern counties of England, beyond the limits of the metropolis, which apparently confirmed beyond all question the conclusion previously suggested, that dampness of soil is an important cause of phthisis to the population living upon the soil.

The reason for the counties of Surrey, Kent, and Essex being the only ones included in the investigation was that the Geological Survey of England, although at that time advancing to completeness in its records of the great formations of the country, had mapped the minute surface geology in these counties only. It was evident that surface peculiarities would require to be 'taken into account quite as much as the great divisions of the geologist; that brick earth, drift gravel, river alluvium, and the like, have an importance in themselves quite apart from the character of the larger formations over which they lie.'

The three south-eastern counties, therefore, formed the only area where the survey then afforded materials for profitable detailed examination of the soil as affecting the health of residents upon it.

The inquiry was carried out by, first, ascertaining the true phthisis-rate of the population, and in the second place noting the numbers of the population in each district that were found 'living upon various kinds of soil and under various topographical conditions.' The results of these two separate lines of investigation were then brought together and statistically compared.

The results of the inquiry are shown in the following general conclusions with which Dr. Buchanan summarised his report:—

1. Within the counties of Surrey, Kent, and Sussex there is, broadly speaking, less phthisis among populations living on pervious soils than among populations living on impervious soils.

2. Within the same counties there is less phthisis among populations living on high-lying pervious soils than among populations living on low-lying pervious soils.

3. Within the same counties there is less phthisis among populations

living on sloping impervious soils than among populations living on flat impervious soils.

4. The connection between soil and phthisis has been established in this inquiry:

(*a*) By the existence of general agreement in phthisis mortality between districts that have common geological and topographical features of a nature to affect the water-holding quality of the soil.

(*b*) By the existence of a general disagreement between districts that are differently circumstanced in regard of such features.

(*c*) By the discovery of pretty regular concomitancy in the fluctuation of the two conditions—from much phthisis with much wetness of soil to little phthisis with little wetness of soil.

(*d*) By the observation that phthisis has been greatly reduced in towns where the water of the soil has been artificially removed, and that it has not been reduced in other towns where the soil has not been dried.

5. The whole of the foregoing conclusions combine into one, which may now be affirmed generally, and not only of particular districts, that wetness of soil is a cause of phthisis. . . .

6. No other circumstance can be detected, after careful consideration of the materials collected, that coincides on any large scale with the greater or less prevalence of phthisis, except the one condition of soil.

Dr. Buchanan had not long completed his investigations, when it became known in England that Dr. Bowditch, of Boston, U.S., had been working on similar lines in America for some time previously, and that he had arrived at identical conclusions. In an address delivered at the annual meeting of the Massachusetts Medical Society in 1862, and afterwards published, he drew attention, and not for the first time, to the remarkable inequality with which he found phthisis to be distributed in the States, and to the connection of this inequality with differences of moisture of soil, and he submitted the two following propositions as containing the essential results of a very extended inquiry:—

'First: A residence in or near a damp soil, whether that dampness be inherent in the soil itself or caused by percolation from adjacent ponds, rivers, meadows, marshes, or springy soils, is one of the principal causes of consumption in Massachusetts, probably in New England, and possibly in other portions of the globe.

'Second: Consumption can be checked in its career, and possibly—nay probably—prevented in some instances by attention to this law.'

He not only proved apparently 'that dampness of the soil of any township or locality is intimately connected, and probably as cause and effect, with the prevalence of consumption in that township or locality,' but even also adduced particular instances as tending to prove that 'some houses may become foci of consumption when others, but slightly removed from them but on a drier soil, almost wholly escape.'

Although, therefore, the priority of discovering a connection between soil-dampness and the phthisis rate is undoubtedly due to Dr. Bowditch, the investigations of Dr. Buchanan are none the less valuable, he having quite independently, and probably upon more complete data, established the prevalence of a similar relation in this country; and, indeed, the researches of both observers obtain additional weight from the fact that they were arrived at almost simultaneously, each observer being entirely unbiassed by the other.

It is also worthy of note, as affording still further support to the results thus obtained both in England and America, that the Registrar-General for Scotland in his Seventh Annual Report, adverting to Dr. Bowditch's work,

stated that, in his opinion, the phthisis mortality statistics in Scotland furnished evidence to the same general effect: among the principal towns, Leith and Edinburgh, the most free from consumption, having also the driest sites, while, on the other hand, Glasgow and Greenock, the most ravaged by this disease, were, beyond all comparison, situated on the dampest sites. The remarkable freedom from consumption of the Cape of Good Hope and South Africa generally, as also of Egypt, as compared with the comparatively high mortality from it in the moist climate of Great Britain, is a fact which also points in the same direction. It has been shown, moreover, in America, by Dr. Andrews, that cases of phthisis are most abundant near the sea, and diminish with increasing distance from it, so that while in Central North America the proportion of deaths from consumption to deaths from all causes is least, the ratio gradually rises as we pass towards either the Atlantic or Pacific Ocean, the numbers being, however, greater on the eastern than on the western coast, while on the northern sea-boards there is a similar increase over districts situated more towards the south.

Hence we may fairly consider the proposition affirming a close relation between tubercular disease and moisture of locality to be of practically universal application.

A certain amount of opposition has, however, been offered to these views, notably, by Dr. Charles Kelly, who, in his Report for 1879, on the Combined Sanitary District of West Sussex, has thrown doubt on these conclusions, basing his statements on certain data collected within that rural area. He there states that, although the phthisis death-rate had been distinctly lowered during immediately preceding years, there had been no contemporary improvements in the system of drainage of the soil to account for the alteration. Dr. Thorne Thorne, on the other hand, has indicated that the large amount of agricultural drainage which had then already been effected throughout the kingdom had been of a sort to produce a similar result in rural districts to that brought about by sanitary drainage in towns, and he at the same time calls attention to the fact that Dr. Kelly offers no explanation of the striking and definite relation shown by Dr. Buchanan to have existed between the amount of diminution of phthisis death-rate and the extent and permanence of the lowering of subsoil water. In the same report Dr. Kelly states his belief that a number of changes, social as well as sanitary, including among them the improved state of the cottages, the rise of wages leading to the children being better clothed and fed, the increase in railway communication, which tends to diminish intermarriage and to cause more interchange of population, have all had their share in the undoubted improvement which has taken place.

In a later report (1887) Dr. Kelly again returns to the subject, and gives a series of comparison tables for the ten years 1876–86 relating to the combined district of West Sussex. He first classifies the different soils into three classes:—

1. The *pervious soils,* which include the upper and lower green sands, the chalk, and the lower Tunbridge Wells sands.

2. The *retentive soils,* which include the Weald clay, the clayey beds of the lower green sand, and the gault.

3. The *moderately pervious soils,* including a long strip of nearly level land between the South Downs and the sea, where the chalk is covered for a depth of fifteen to fifty feet with loam and brick earth. The surface of this soil rises gently from the sea towards the Downs, so that, although in some parts the clays are retentive, yet the slope towards the sea enables surface water to flow away readily, except in some of the low-lying brooklands.

This classification is followed by a table showing the various death-rates on these different soils :—

Nature of soil	Population	1876–86 Death-rate per 1,000,000 living at all ages from		
		Phthisis	Lung diseases	All causes
Pervious . . .	33,820	1,514	2,131	14,852
Moderately pervious	29,640	1,467	1,892	14,463
Retentive. . .	23,530	1,542	2,583	14,942
West Sussex . .	86,990	1,506	2,172	14,741

These figures appear to show that the mortality from lung diseases varies considerably, being much higher or retentive than on porous soils, while the mortality from what is now registered as phthisis and from all causes is very nearly the same on each variety of soil.

It should, however, be remembered that in this West Sussex district, as indeed throughout England, there has been a great reduction in the phthisis mortality since Dr. Buchanan's inquiry into the subject for the decade 1851–60. Moreover, the assumption runs through all Dr. Kelly's arguments that the *relative* wetness of soil in the six registration districts with which he is concerned remains in later times as it was in 1851–60. What his statistics may be taken to show is that, all the varieties of soil being now equally healthy, the cause of the phthisis deaths which still occur has to be sought for in some other direction.

Not a particle of evidence is adduced on this point, nor is the operation of sanitary measures upon the soil in the several districts even spoken of. In his Sixth Annual Report (1879), indeed, it is stated that there has been 'no change whatever in the drainage' of these rural districts, but this statement is too bald to be of much import. The assumption, too, pervades his argument that soil wetness is *the* cause of phthisis, whereas all that has ever been claimed for it in this connection is that it is *a* cause.

The relations of phthisis to *season* and *temperature* are somewhat obscure, as might be expected, seeing that the duration of the disease may extend over not only months, but years. Buchan and Mitchell, however, have shown that mortality from tabes shows a definite relation to the temperature, the maximum extending, like that of summer diarrhœa, from the middle of July to the middle of September, while the absolute minimum is found by them to last from the end of December to the beginning of February.

According to these observers, also, a curve of the seasonal relations of phthisis mortality shows that 'the absolute minimum occurs in the last week of September, after which it begins steadily to rise ; in the middle of November it rises still more rapidly ; during the last three weeks of December it falls a little ; rises again in the beginning of the year, and remains steady until the second week of March, when it rises to the annual maximum during March, April, and May. From the middle of July to the middle of November it is below the average. This is one of the most constant curves in its main features from year to year.'

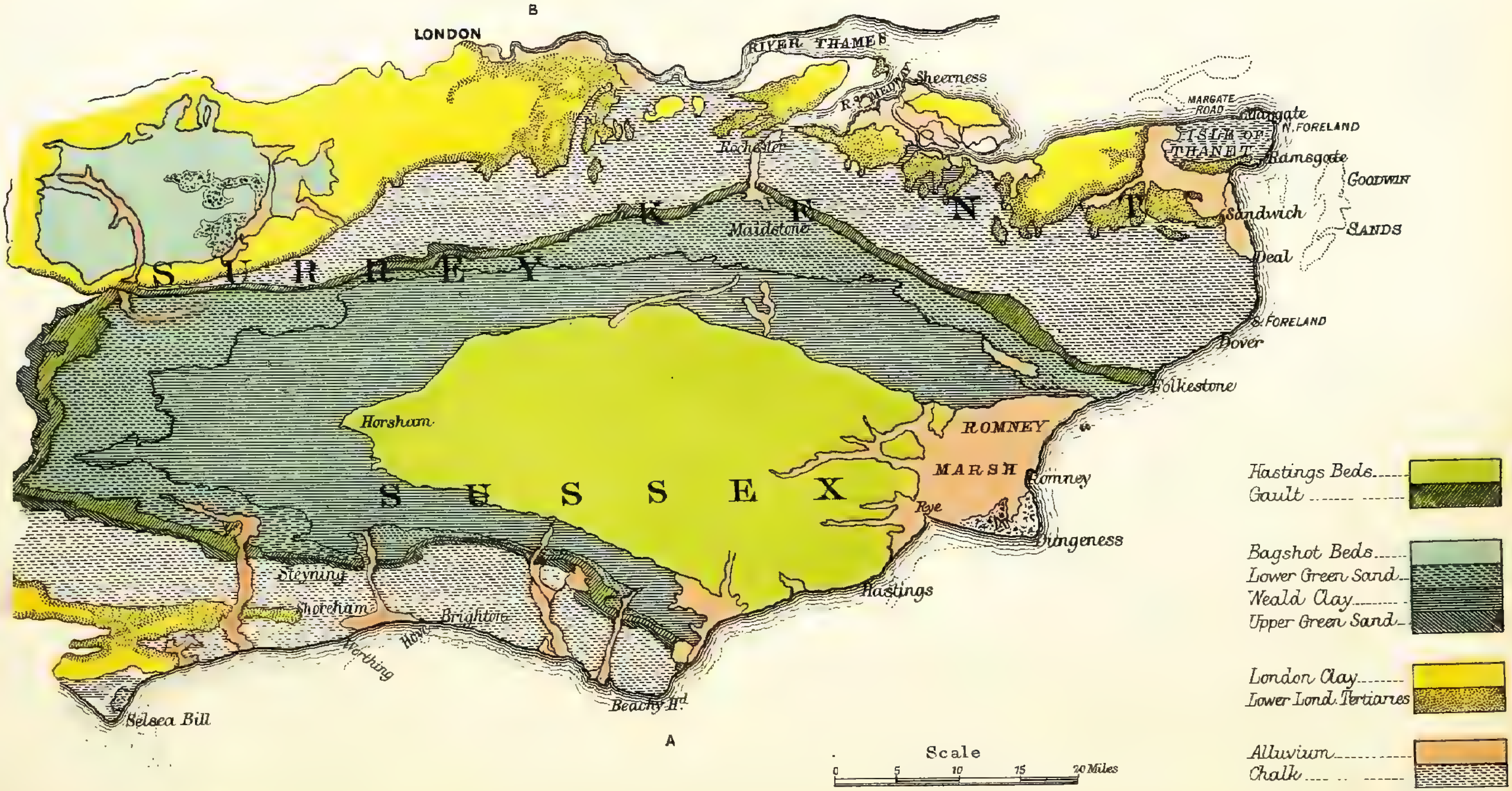
The Bacillus Tuberculosis

To Koch is undoubtedly due the honour of having discovered the microparasite which is pathognomonic of the disease under consideration. Prior to the publication of his researches, indeed, numerous observers had described various micrococci and other organisms which they had found in tuberculous material, but their significance has not been confirmed by subsequent research.

Pl. IV.

[Copeman]

MAP OF THE SOUTH-EAST OF ENGLAND (KENT, SURREY & SUSSEX) *Reduced from the Geological Survey 1868.*



West, Newman lith.

Map shewing the
REGISTRATION DISTRICTS
— OF —
KENT, SURREY AND SUSSEX.

The figures refer to the order of the districts in respect of their consumption mortality, on the first table of Dr. Buchanan's report on the relation of phthisis to dampness of soil.

West, Newman lith.

According to Koch, the tubercle bacilli appear in the form of rods, the length of which is usually equal to that of half a red blood-corpuscle, although this may vary somewhat with the method of staining employed. They are very thin and rounded at the ends. They may be straight, but more commonly are slightly curved, and as they often occur in pairs, the double curve seen in such a case may suggest the notion of the commencement of a spiral; these appearances, together with their size, being sufficient to differentiate them from other bacilli which most nearly resemble them.

When first the tubercle bacillus was discovered, it was thought the invasion of the tissues by the micro-organism was the cause of the development of phthisis, but of late the opinion has been gradually gaining ground that the bacillus, the spores of which must be abundantly present in the air (and possibly in the soil), particularly in certainly localities, merely finds a fitting nidus in tissues of a lessened power of resistance, whether this be acquired or be due to hereditary taint. The multifarious forms in which tuberculosis presents itself, both in man and in the lower animals, would certainly appear to support this view, which, if it be confirmed by subsequent observations, will necessitate further research in other directions to elucidate the true ætiology of the disease. Seeing, however, that the bacilli may almost invariably be found not only in affected tissues, but also in the sputum in cases of tuberculosis of the lungs, their detection will always form a point of considerable diagnostic importance, so much so indeed, that to use Koch's own words, 'A doctor who shall neglect to diagnose phthisis in its earliest stage by all methods at his command, especially by examining the sputum, will be guilty of the most serious neglect of his patient.'

In the light of our present knowledge of the subject, the efforts of preventive medicine must be directed in the first place to the removal of those conditions which appear to bring about a tendency to phthisis, such as dampness of soil and of dwellings, overcrowding, and possibly the consumption of the milk of diseased cows and of tuberculous meat.

At the same time, contamination of the soil and air by the sputum of tuberculous patients should receive due attention, this being effected as far as possible by its reception on paper or rags, which should be immediately burned, or into spittoons containing some powerful disinfectant. The removal of soil-dampness is of course only to be carried out by means of efficient drainage operations, this being a problem for the engineer rather than the medical officer of health.

The maps are copied from those appended to Dr. Buchanan's report on the distribution of phthisis as affected by dampness of soil, contained in the Tenth Report of the Medical Officer of the Privy Council (1867). (Plates IV. and V.)

Plate IV. shows the broad geological features of the district investigated; the distribution of the main formations, of the broader tracts of alluvium, and of the more important surface coverings of gravel and the like being exhibited in a very exact and reliable way. From its scale, however, many points cannot be demonstrated upon it, thus (1) narrow tracts of alluvium along streams are not shown; (2) brick-earth is not separated from gravel; (3) the divisions of the Bagshot beds are not given—they are of small moment; (4) the divisions of the Lower Greensand are not shown, and, what is more important, (5) the divisions of the Hastings beds into sands and clay is not made; these divisions are made in nature by no long and well-defined boundaries, but by very irregular and multitudinous lines which could not be exhibited on this small map; (6) faults are not marked, and (7) of the formations that are shown, very small detached patches are, from the necessity of the case, omitted.

Plate V. shows the registration districts of Kent, Surrey, and Sussex, numbered in the order of their phthisis death-rate, as shown in the table appended, which is copied from Dr. Buchanan's report. Of these the statistics relating to those numbered 1, 2, 8, 14, 23, 27, 31 and 41 are unreliable, for various reasons, such as the number of invalid visitors or the migratory nature of the population.

Registration Districts in the Order of their Proper Mortality from Consumption.
(See Maps)

1. Sheppey
2. Hastings
3. Dartford
4. Epsom
5. Milton
6. Godstone
7. North Aylesford
8. Thanet
9. Dover
10. Bromley
11. Steyning
12. Chertsey
13. Croydon
14. Hoo
15. Cranbrook
16. Richmond
17. Kingston
18. Elham
19. Blean
20. Bridge
21. Gravesend
22. East Grinstead
23. Tunbridge
24. Reigate
25. Eastbourne
26. Farnham
27. Medway
28. Hambledon
29. Battle
30. Canterbury
31. Romney Marsh
32. Hollingbourne
33. Malling
34. East Ashford
35. Sevenoaks
36. Guildford
37. Farnborough
38. Eastry
39. Faversham
40. Rye
41. Brighton
42. Maidstone
43. Cuckfield
44. Dorking
45. Uckfield
46. Hailsham
47. Ticehurst
48. Worthing
49. West Ashford
50. Lewes
51. Tenterden
52. Horsham
53. Westhampnett
54. Midhurst
55. Thakeham
56. Petworth
57. Westbourne
58. Chichester

Diarrhœa

In late summer and early autumn diarrhœa is a disease which is very apt to prevail epidemically, rural districts with a scattered population being, however, less affected than large densely populated towns. As a fatal disease it is confined almost entirely to children under five years of age, of whom thousands are swept away annually by what Fodor truly terms 'the infants' destroying angel;' but it is a mistake to suppose that adults are not affected, since of 24,157 attacks recorded in Leicester during the last four years (1885–1889) 16,506 were among persons over ten years of age.

The subject was carefully investigated in 1859 by Dr. Greenhow, who arrived at the conclusion that in those places where it prevailed most severely, a local cause could usually be traced, consisting either of a tainting of the air with the products of decomposition of organic matters, particularly of human excrement, or of a contamination of the water-supply. These results, however, have not been by any means corroborated in subsequent inquiries; other conditions, such as temperature of the air and of the soil and the amount of rainfall, having gradually come to be considered of more importance. Organic contamination of both soil and water may, it has been found, exist to a considerable extent without the necessary supervention of summer diarrhœa, provided that other circumstances are unfavourable.

The seasonal curve of diarrhœa shows that the mortality usually begins to increase about the middle of June, rising rapidly to a maximum at the end of July or beginning of August, and falling somewhat less rapidly during August, September, and October. Atmospheric heat is by no means an essential factor in the production of this disease, however, since it is never, even in its fatal forms, really absent from the population at any period of the year, being met with in winter as well as summer, although not nearly to the same extent. The disproportionate mortality during the summer is principally owing to the disproportionate rate of attacks among a population, the fatality of a given number of attacks in the one and the other season being not more diverse than 3 : 1 in the summer as compared with the winter. In the second place the epidemic development of the malady does not always correspond with the commencement of summer atmospheric temperature, especially when the latter is exceptionally early. Moreover, as Fodor has shown as the result of his observations at Buda-Pesth, there may be no apparent connection between the air temperature and the curve of diarrhœa, since, while in the summer of 1863, which was very warm, the number of cases was small, in the follow-

ing year, which was much cooler, the disease was very widespread. He states also the disease usually asserts itself on a sudden, but only after a certain degree of warmth has continued for a longer or shorter period, 'as if,' he adds, 'the virus in the soil had first to ripen.' Turner also, in the 'Medical Times and Gazette' for 1879, endeavoured to show that a temperature of over 60° F. must last at least three weeks before diarrhœa becomes excessive. Again, the percentage of deaths from this disease is not only much higher in towns than it is in villages, but in some cities and in certain parts of cities the disease is much more prevalent, although there is no difference of temperature to account for it. Diarrhœal epidemicity, therefore, and the atmospheric temperature by no means invariably correspond, although not unfrequently the highest point of prevalence of the disease may occur at about the time when the highest summer temperature is reached, or a little later. There is an even more remarkable lack of correspondence between the decline of the two things, for although the prevalence of diarrhœa lessens with the falling temperature in October and September, it does not do so proportionately to the fall in the air temperature, the extent to which it is present among the population being considerably greater than it would be with a similar temperature in the earlier months of the year.

In the same way it is not possible to trace any direct connection between a tendency to putrefactive changes in articles of food and drink, such as might, in certain cases, be expected to occur with a high temperature, and the prevalence of diarrhœa. Milk particularly is very liable to undergo decomposition in warm weather, and it has been thought that its extensive use as a food for young children, especially those only recently weaned, might account in great measure for the special incidence of the disease during the first few years of life, but this view is obviously no longer tenable, except in so far as that such a condition of things might predispose the system to suffer more severely when attacked.

Dr. Ballard has recently pointed out that there is, on the other hand, a very considerable correspondence between the prevalence of diarrhœa epidemics and the temperature of the earth at a distance of four feet from the surface. In a diarrhœa town, no matter what the temperature of the atmosphere may have been in the latter part of the spring quarter, in May or June, or even in July, the epidemicity does not become markedly manifest until the thermometer, four feet below the surface, shows a temperature of about 56° F. (13° C.). He shows that when this temperature is reached, and so long as it is maintained, the epidemic prevalence continues there, and commonly reaches its acme about the same time as the four-feet earth temperature. An exception is occasionally seen to this, the prevalence of the disease commencing to decline before the four-feet earth temperature has reached its highest point. This is noticeable when the earth temperature has remained for some time at about 56° F., such sustained high temperature of the earth appearing capable of exhausting the potency for evil of the soil factor of the disease, whatever it may be, before the extreme elevation has been reached. The decline of an epidemic again shows little or no relation to that of the air temperature, but often a very close connection with the extremely gradual and slower fall of the four-feet soil temperature, so that, although the atmospheric temperature may be much lower in autumn than in summer, the prevalence of diarrhœa may be more marked. It requires a continuance of a fairly high air temperature for a considerable period before the soil temperature, at a depth of four feet, reaches 56° F., and until this point is reached, the cause of the disease appears to be dormant; but once that temperature in the soil is touched in a diarrhœa town, an epi-

demic arises more or less explosively, declining later in a much more leisurely manner, so that the different relation of air temperature to the prevalence of diarrhœa in the spring, and in the later months of the year, is still more marked than if the summer and autumn months be compared.

Dr. Tomkins, of Leicester, who for several years has recorded the temperature of the earth at one foot and four feet levels during the warm months, shows very conclusively that it is not till the temperature of the earth, at a depth of one foot, has reached about 60° F. (15°·53 C.), and stands at some 4° F. less than this at four feet, that diarrhœa begins to prevail to any marked extent. He, however, regards the temperature at a depth of one foot as the most significant.

Reviewing in 1886–88 statistics of diarrhœa and infant mortality in the city of Buffalo, Snow found that thirty-one per cent. of the deaths under one year of age were caused by acute intestinal disease. He found that there was no constant relation between a high average atmospheric temperature and the largest number of fatal cases, but that, on the other hand, greatest diarrhœa mortality occurred always in the month in which the minimum atmospheric temperature attained its highest average range, and this altogether independent of the circumstance that such month was not necessarily that of maximum highest mean average temperature. And this fact would appear not out of harmony with the results of Ballard's researches. The following table giving the number of deaths in Buffalo for July and August for each of three years, with the mean average temperature and the average minimum temperature, illustrates the fact upon which Dr. Snow insists:—

Table of Temperatures at Buffalo for July and August 1886, 1887, *and* 1888.

—	Diarrhœa. Deaths	Mean average temperature of atmosphere for each month		Average minimum night temperature for each month	
1886, July	144	69·4° F.	20·77° C.	60·3° F.	15·72° C.
„ August	141	67·2	19·55	60·3	15·72
1887, July	265	68·4	20·22	67·5	19·72
„ August	168	74·6	23·66	64·2	17·88
1888, July	189	67·4	19·66	59·6	15·33
„ August	212	67·4	19·66	64·0	17·77

A study of meteorological conditions during two of these years seemed to show that cholera infantum is much more prevalent in a dry than in a wet season, this possibly being in turn due to the fact that in a dry season the temperature of the soil would be likely, other things being equal, to reach a higher point than in the opposite case. This same fact has been insisted on by Fodor, who states, as the result of his experience, that an exceptional rainfall occurring in the midst of even the most violent epidemic will be followed, after from eight to ten days, by a large reduction in the death-rate, but that on cessation of the rain the disease may assert itself afresh. The results of Power's investigations at Leicester are also in harmony with this statement.

In the table compiled by Dawson Williams (p. 365), the two years 1887 and 1888 are chosen for comparison, because 1887 was exceptionally warm and dry, while 1888 was unusually cold and wet. The table shows also that the endemic prevalence of fatal diarrhœa in London may occur with a lower air temperature than 60° F.

A certain amount of moisture of the soil, however, is favourable to the prevalence of diarrhœa, and as warmth is also a necessary factor, it is highly probable that it is to microphytic processes going on in the upper layers of the soil that the epidemic spread of the disease is due. This would afford an explanation of the fact that summer diarrhœa is, especially, a disease of cities

Table showing Number of Deaths in London from Diarrhœa in Two Consecutive Years (Dawson Williams)

1887. A Warm Summer							1888. A Cold Summer						
No. of week	Week ending	Deaths from diarrhœa			Range of minimum temperature of air	Mean weekly minimum temperature of air	No. of week	Week ending	Deaths from diarrhœa			Range of minimum temperature of air	Mean weekly minimum temperature of air
		0 to 1 year	1 to 5 years	All ages					0 to 1 year	1 to 5 years	All ages		
21	May 28	4	5	10	35·9 to 47·0	42·8	21	May 26	6	1	9	40·6 to 46·0	43·2
22	June 4	5	3	12	44·4 „ 50·8	47·5	22	June 2	9	2	19	35·0 „ 50·6	44·3
23	June 11	2	7	9	43·4 „ 54·8	49·6	23	June 9	12	2	18	46·5 „ 53·6	49·8
24	June 18	10	4	20	47·9 „ 53·6	51·0	24	June 16	10	3	16	46·3 „ 50·0	47·8
25	June 25	21	4	30	44·0 „ 51·7	49·1	25	June 23	15	3	18	45·5 „ 54·5	48·1
26	July 2	43	4	52	42·5 „ 55·5	50·0	26	June 30	21	5	36	49·2 „ 60·1	54·3
27	July 9	107	17	133	50·9 „ 60·0	55·3	27	July 7	29	14	51	46·2 „ 54·7	50·8
28	July 16	265	33	312	55·0 „ 59·2	57·2	28	July 14	60	7	72	42·8 „ 55·1	48·2
29	July 23	389	73	483	44·8 „ 57·4	49·7	29	July 21	46	7	62	48·6 „ 55·1	52·8
30	July 30	435	59	517	51·7 „ 58·9	55·5	30	July 28	68	15	89	49·2 „ 56·1	53·8
31	Aug. 6	354	60	436	46·3 „ 54·1	49·7	31	Aug. 4	105	11	121	45·8 „ 53·0	50·4
32	Aug. 13	330	55	412	50·8 „ 57·4	54·3	32	Aug. 11	104	26	138	47·1 „ 59·0	54·3
33	Aug. 20	259	40	316	41·0 „ 53·3	48·5	33	Aug. 18	128	24	162	45·2 „ 55·5	48·6
34	Aug. 27	148	25	191	45·9 „ 60·1	51·2	34	Aug. 25	138	42	192	45·7 „ 54·5	51·8
35	Sept. 3	97	23	132	51·8 „ 58·9	55·9	35	Sept. 1	112	24	144	41·5 „ 52·3	48·4
36	Sept. 10	72	15	107	40·7 „ 54·5	48·9	36	Sept. 8	96	29	131	45·0 „ 57·0	51·2
37	Sept. 17	55	8	73	43·1 „ 52·2	47·4	37	Sept. 15	87	26	122	41·4 „ 53·0	44·7
38	Sept. 24	33	5	45	43·3 „ 50·1	47·0	38	Sept. 22	60	15	78	47·1 „ 54·3	50·0
39	Oct. 1	27	9	43	33·6 „ 47·7	40·9	39	Sept. 29	61	13	77	45·6 „ 55·4	49·9
40	Oct. 8	10	5	18	43·8 „ 49·0	47·5	40	Oct. 6	52	15	72	29·7 „ 38·5	33·5
41	Oct. 15	13	3	24	25·3 „ 46·3	35·0	41	Oct. 13	31	8	43	27·9 „ 42·1	36·2
42	Oct. 22	4	2	11	26·8 „ 38·5	35·0	42	Oct. 20	24	10	42	31·4 „ 39·7	34·4
		2,683	459	3,386					1,274	302	1,712		

having a polluted soil, although the organic matter present need not necessarily be of a fæcal or excremental nature. Diarrhœal mortality is apt to be high where dwellings are built upon made ground, upon the refuse of towns or market gardens, or where the soil is fouled by the escape of sewage from imperfect drains, sewers, or cesspits, or by soakage from midden-heaps. It is therefore to be found most prevalent in those parts of towns where the soil is most polluted, as in Leicester, which has the unenviable notoriety of the highest diarrhœal mortality of any of the large towns of England, those parts in which the soil is 'made' accounting for the larger proportion of the fatal cases.

The association of high diarrhœal epidemicity with certain geological characters of the soil is another important point for the elucidation of which we are mainly indebted to the researches of Dr. Ballard. The one condition which he finds gives an almost, if not entirely, absolute exemption from the disease, is foundation of the dwellings of a locality on hard and impervious rock. In such a locality, the disease may indeed spread if introduced from without, but with this exception, the disease is so rare that no serious or fatal case may occur, as in some parts of Devon and Cornwall, during a long series of years. On the other hand, the looser and more pervious the soil, the more distinctly is it found, other conditions being equal, to be conducive to a prevalence of diarrhœa among those who live in such a district, sand, gravel, and marl being those soils which are most favourable to a high diarrhœal mortality; while in the case of gravel, the smaller its particles—the nearer it approaches to sand in fineness, or conversely the more its stony element predominates—the greater its likeness to rock in coarseness, the more or less obvious will its relation to the prevalance of diarrhœa appear.

Stagnation of air, whether induced by geographical situation, to the arrangement of streets, or to the construction of houses, as when crowded together on a small area, or built back to back so as to hinder or altogether prevent efficient ventilation, has an important influence on the progress of the malady during a period of epidemic prevalence, acting in all probability through the retention in such locality of the organisms given off by the soil under circumstances which have been previously mentioned. High winds, on the contrary, by ventilating the soil and removing the strata of stagnant air immediately above it, will check the disease while they continue, and in localities where free circulation of air is permitted and where dwellings are well ventilated, an epidemic never gains so firm a footing; the explanation of this fact being that such conditions are in the one case favourable and in the other unfavourable to the dissemination of the soil products which, as far as our present knowledge leads us, must be considered the essential cause of the disease.

Dr. Klein, in the course of an extensive microscopical investigation, has failed to find anything in the tissues, blood, or excreta of a number of diarrhœa cases to indicate that any definite microbe is concerned in the production of the disease; but Dr. Ballard, arguing from the fact that in certain groups of cases in which it is apparently communicated from person to person by means of the exhalations from the stools, believes that in the excretions of such cases a specific micro-organism will yet be found. The conclusions at which he has arrived as the result of his researches may best be given in his own words:—

'That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism, not yet detected, captured, or isolated.

'That the vital manifestations of such organism are dependent, among other things, perhaps principally, upon conditions of season, and on the presence of dead organic matter, which is its pabulum.

'That, on occasion, such micro-organism is capable of getting abroad from its primary habitat, the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material, and of using such organic material both as nidus and pabulum in undergoing various phases of its life-history.

'That in food, inside of, as well as outside of the human body, such micro-organism finds, especially at certain seasons, nidus and pabulum convenient for its development, multiplication, or evolution.

'That from food, as also from the contained organic matter of particular soils, such micro-organisms can manufacture by the chemical changes wrought therein, through certain of their life-processes, a substance which is a virulent chemical poison (probably ptomaine).

'That this chemical substance is, in the human body, the material cause of epidemic diarrhœa.'

In connection with the fact that rising currents of ground-air may carry bacteria out of the soil into the atmosphere above, it is worthy of note, perhaps, that observations have been recorded by Dr. Tomkins on bacteria in the *air* in diarrhœal districts in Leicester. His experiments were directed to ascertain the relative number of germs present in the atmosphere in different parts of the town, and particularly in those portions most affected, both before and during an epidemic. While diarrhœa was prevalent he found from two to three times as many microbes in the air as before or after this period, while in the particular region specially affected there were fourfold as many as in other districts where the disease did not prevail. None of the bacteria, however, have been isolated or worked out, and the mere presence of germs in quantity is no positive proof of their causative agency, so that these experiments cannot be regarded as creating anything more than a presumption in favour of the influence of pathogenic organisms in this disease, more particularly as no simultaneous bacteriological examination of the soil was carried out.

Dysentery

Many writers have considered that both dysentery and malaria are due to a similar cause, for the reason that these diseases appear equally to prevail in almost all situations, such as the vicinity of the swamps and sluggish rivers of tropical and sub-tropical countries, which are the breeding-ground of intermittent fevers.

The two diseases indeed may occur together in the same patient and at the same time, and Dr. Aitken has stated that if a boat's crew be sent ashore in a tropical climate, and exposed to paludal miasmata, the probabilities are that of the men returning on board some will be seized with dysentery and some with intermittent fever. It is also a well-established fact that where, both in Great Britain and other countries, the tendency to attacks of malaria has been diminished by improved drainage, and the conversion of marshes into cultivated land, there also dysentery has gradually diminished to an equal extent. There are, however, places in which dysentery occurs even in an epidemic form, but which never under any circumstances yield ague, while also all aguish districts are not necessarily dysenteric. Moreover, the two diseases never graduate the one into the other, so that although it is possible that the real cause of dysentery is some poison allied to that which produces malaria, the two need not be identical.

Dysentery, although still common in some parts of the world, has not occurred epidemically in London since 1762, but isolated cases are still to be met with which have been imported into this country from districts on the

Mediterranean coast line, from India, Africa, Central America, and elsewhere. Until within recent years, however, small outbreaks of the disease were of constant occurrence in Millbank Prison. These were investigated by Dr. Baly, and subsequently by Dr. Maclean, both of whom believed them to be related to emanations from the soil on which the prison stands, consequent on the decomposition of organic matter. It is more probable, however, that the water supply rather than the ground air was at fault, since when in 1854 the direct supply of water from the river Thames was exchanged for that obtained from the artesian well in Trafalgar Square, dysentery suddenly declined, and from that time has been unknown.

That soil laden with products of decomposing sewage and the like may, however, be an important factor in the genesis of the disease is amply proved by an interesting account given by Fagge of a series of epidemics which occurred in the Cumberland and Westmorland Asylum during the years 1864, 1865, and 1868. For a long time no cause for the production of the disease could be traced, although it had been thought possible that it might be connected with the fact that the sewage of the asylum, after being thrown into a large tank, was distributed over a field about three hundred yards distant. On hot and sultry evenings an offensive smell was often noticed, and Dr. Clouston, the medical superintendent, then had the sewage carried away to a distance through a covered drain, with the result that no fresh cases of dysentery occurred. An investigation was then made as to the exact meteorological conditions which had existed during the prevalence of the epidemic, and it was found that within a week before the day on which each patient fell ill there had always been either hot sultry evenings, with no wind in the night, or northerly winds which blew from the direction of the field which was being irrigated. Male and female patients, too, were attacked at different times, according as the exact direction of the wind was such as to carry the sewage emanations either to one or the other of the parts of the building which the two sexes severally occupied.

In the following year five cases of dysentery all occurred within a week after the sewage had again been allowed to flow over the field during a calm night, when the direction of the wind happened to be towards the asylum. From this time the disease entirely disappeared for more than two years, but on another attempt being made to get rid of the sewage by irrigation, although special precautions were taken, and another field chosen, six patients contracted dysentery within a couple of months of the commencement of the experiment. All the cases occurred in that part of the asylum nearest the field, and towards which the wind had been blowing continuously for eight days before the outbreak occurred. The subsoil of the land surrounding the asylum was a stiff clay which was impermeable to water, and which consequently was quite unfit for irrigation purposes, the sewage simply stagnating thereon for an indefinite length of time.

Season has apparently some influence on the prevalence of dysentery, as both in tropical and temperate climates it is more apt to appear in autumn than at other times of the year. The *temperature* of the atmosphere, or perhaps of the soil, is also a factor which must be taken into consideration, as it has not unfrequently been observed that the disease has occurred to a greater extent in years which were exceptionally hot.

Whether any micro-organism be concerned in the production of dysentery is not at present known; but some observers maintain that it is certainly contagious. The researches of Hornan and Hertwig in Norway would seem to prove that the disease may be conveyed by healthy persons from infected places to other spots where the disease had not before appeared, and, arguing

from the analogy of cholera and enteric fever, it appears quite possible that there may be present some organism which is capable of multiplication in the body, and which reaches the outer world in the alvine evacuations.

Lead-Poisoning

This disease, or rather a form of it which has been very prevalent of late years in some parts of England, must, in the light of recent researches, be included in the list of those which are predisposed to by certain conditions of the soil, although at first sight the relation may not appear obvious. In Yorkshire particularly, lead-poisoning has always been more or less prevalent owing to the trades carried on there, the file-cutters being specially liable to suffer from this disease, but after eliminating all cases of lead-poisoning arising from trade, a large number still remain for which the only cause appears to be the taking of lead into the system through the medium of the drinking water; this supposition being confirmed by chemical examination of the water which has been found to contain varying but often large quantities of lead.

The poisonous nature of the water in the affected areas is due to its capacity for taking up lead from the pipes by means of which the water is distributed. Such water is obtained from high gathering grounds on the moors, and is very soft and otherwise of excellent quality, and although the amount of albuminoid ammonia is usually somewhat high, in the absence of chlorides and nitrates this must obviously be of vegetable origin, the peat which is so plentiful at the gathering grounds occasionally also giving the water a brownish tint. Where a town or district has a low-level supply also, it is found that this has no such solvent action on lead; the only reason for this difference being found apparently in an acid reaction of the high-level water, that obtained from the low-level gathering grounds, on the other hand, being neutral or faintly alkaline.

As to the nature of the acid which is present there is considerable divergence of opinion, since its small amount makes an accurate determination a matter of great difficulty. It appears, moreover, that the acid which is found in the water obtained from the service pipes is not in some cases the same as that to which the acid reaction of the water at the gathering grounds is due, some chemical decomposition apparently taking place during its passage through the reservoirs and mains. The amount present, therefore, is generally expressed in terms of sulphuric acid, which by some observers is believed to be that which is always present in the water. It has been suggested that such free sulphuric acid might be derived from the oxidation of iron pyrites in the shale which usually underlies the beds of peat; but even though it may be present in the water of the moorlands, it by no means follows that the acid will be the same when the water reaches the lead service pipes, since, meeting with salts, it may have decomposed these with the formation of sulphates, other acids being set free.

That this is often so can be shown by neutralising the water, evaporating to dryness, and igniting the residue, when a carbonate is formed, thus proving that the acid now present is of an organic nature. It is also non-volatile, since usually none appears to be lost on concentration of the water. An obvious source from which such acid might be derived, is the peat of the moors, since it has been known for some time that the decomposition of peat and other vegetable substances gives rise to the formation of several bodies which have been described under the names of crenic, apocrenic, ulmic, and humic acids. Unfortunately, however, the literature of the subject is

extremely scanty, and there is considerable doubt whether any of these acids have ever been prepared in an absolutely pure state. In support of the opinion that it is to the presence of one or more of these bodies that the reaction of the water is due, it may be mentioned that where the peat is most abundant the acid reaction and the amount of organic matter evidently of vegetable origin are most noticeable.

As suggested by Mr. Power in his memorandum on lead-poisoning from certain public water-supplies, contained in the Report of the Medical Officer to the Local Government Board for 1887, it is possible, however, that yet another factor has to be considered. He believes that the action of the water on lead might be due to the growth of micro-organisms in the water, basing this opinion on the facts: (1) that the action on lead presents marked seasonal variations, being most intense in the autumn, particularly in September, October, and November; (2) that instances are found where the ability to act on lead has been newly acquired by a water-supply, so suddenly and in such a manner that a great quantity of lead-poisoning is produced, without any known change in the sources of water-supply, among the inhabitants of a town that had previously been unacquainted with the disease; and (3) finally that the introduction of some comparatively small portion of a plumbo-solvent water into the total water-supply of a town has appeared to confer upon the whole of such supply the power of dissolving lead from the domestic service pipes of the town.

The growth of bacteria is naturally favoured by warmth, so that the fermentation processes would be most active in the hottest part of the year, when also a somewhat lessened rainfall and greater evaporation would tend to the relative as well as absolute increase in the amount of the products of the life-processes of the micro-organisms in the water, and, as has been stated, it is apparently in the few months immediately following the latter part of the summer that the effects of the increased action of the water on lead are most prone to manifest themselves.

If this be so, it does not necessarily disprove the truth of the acid theory, as it is quite possible that the organic substances which yield the acid detected in the water may, at any rate in part, be the result of the presence of bacteria, while some may, on the other hand, be directly derived from the peaty soil. It is hardly necessary to add that the presence of so large an amount of organic matter in the water, as is shown by analysis, would form a most favourable pabulum for the development of micro-organisms, especially when exposed to light and air in the uncovered reservoirs. In this connection it is worthy of note that in a number of places visited for the purpose of investigating this subject, the sudden increase in the amount of lead-poisoning, which first appeared in 1888, followed the dry year 1887, when in Sheffield, for instance, the rainfall for the twelve months was the lowest that had been recorded for fifty years. The result of this drought was that when afterwards rain first fell in any quantity a considerable amount of storm-water which would usually have been diverted into other channels was allowed to pass into the reservoirs, into which it would be likely to carry countless numbers of bacteria and their spores, which would usually be more or less perfectly removed by filtration through the soil, and these would rapidly multiply in the comparatively stagnant water.

Dr. W. R. Smith has conducted a series of biological experiments on behalf of the Local Government Board for the purpose of determining, if possible, whether in waters which have been proved to possess considerable plumbo-solvent power, microphytes are to be found which are capable of working, by their life processes, acid changes in artificial culture media. So

far as these experiments have gone, although they are not yet numerous, nor, according to Dr. Buchanan, at all conclusive, their results appear to be affirmative, since the growth of some micro-organisms obtained from waters of this class is accompanied by a distinctly acid reaction in the media in which they have been grown. Further observations are, however, needed before the matter can be considered to have been placed on a sufficiently satisfactory basis to give definite indications as to the treatment necessary for obviating a source of grave danger to a considerable section of the community, and Dr. Buchanan has pointed out that such researches should be primarily pursued by local investigations into the environments of the various water sources, and into the conditions affecting the distribution of such water, observing always the conditions of time and place surrounding the waters that have the power of acting on lead, and comparing them with the conditions that environ the waters which do not show that power. Meanwhile, seeing that it is apparently to the presence of free acid of some kind or other that the action of these plumbo-solvent waters is due, the logical proceeding is obviously to neutralise the acid, either with carbonate of sodium, with lime, or with carbonate of calcium in the form of chalk or limestone. That such treatment, when properly applied; is an efficient agent in preventing the solvent action of water on lead has been proved in Dessau, which is, like many of the towns of Yorkshire and Derbyshire, supplied with soft water. This water, which showed an acid reaction to which its lead-dissolving power appeared to be due, has become quite inoperative in this respect since a method of neutralising the acid has been successfully carried out, and it would appear that a similar line of treatment has been equally efficacious in certain districts in this country. (See also WATER, *ante*, p. 256).

TETANUS

It is usual to recognise a traumatic and an idiopathic form of this disease, but the results of modern research all tend to support the view advanced by Verneuil that tetanus is never of spontaneous origin, but always arises from traumatic infection. The active agent in the causation of the disease would seem to be a micro-parasite first discovered by Nicolaier in garden-earth and subsequently by Rosenbach in human beings suffering from tetanus. Nicolaier, experimenting on mice, guinea-pigs, and rabbits, found that when soil from fields, gardens, or roads was introduced subcutaneously in these animals, clonic spasms of the parts nearest the point of inoculation were produced, and that this was followed in about twenty-four hours by general tetanus. Rosenbach induced similar effects in guinea-pigs and rabbits by implanting beneath the skin small pieces of tissue obtained from the neighbourhood of the wounded part in a man dying of tetanus. The disease was not only produced in the animals first experimented on, but by inoculation of material from the neighbourhood of the wound from case to case it was propagated through a long series of other animals. In each case the bacillus could be found in the tissues near the point of inoculation, but not in the blood or any of the internal organs. It is an interesting point that in cases of tetanus in the human being also, the bacillus has never been demonstrated in the blood, or tissues other than those at the site of the lesion; and, moreover, inoculations with tetanic blood alone have never given anything but negative results, while when pus or lymph from the neighbourhood of the wound was used, positive results have for the most part been obtained. It would appear, therefore, that the bacillus produces a ptomaine which, when absorbed into the blood, gives rise to the characteristic symptoms of the disease. This idea is, of course, strongly supported by the fact that the bacillus is only found in the neighbourhood

of the wound, and Brieger states that he has separated from an impure culture of the bacillus a body to which he has given the name of *tetanine*, because it produced tetanus in animals even when injected in minute quantity, by virtue of its extremely poisonous effect on the nerve-centres. He succeeded, moreover, in obtaining a similar ptomaine from the amputated arm of a tetanic patient, and he believes that his experiments prove that the disease is due to a species of septic intoxication.

The question of the identity of traumatic and so-called spontaneous tetanus is a most interesting one, and would seem to be strongly supported by experiments carried out by Lampiasi, who, starting from a case of spontaneous tetanus, obtained a virus, which after the lapse of two years was still capable of inducing tetanus in a virulent form. Earth also is capable of retaining its infective property unimpaired for a considerable length of time, specimens which had been kept in a laboratory for between three and four years having caused typical tetanic attacks when inoculated into animals. This point is demonstrated by Dr. Peyraud in an account of some experiments carried out with soil taken from a covered-in enclosure in which wine was stored, and which had not in any way been cultivated since the store was erected. With this soil he obtained positive results in all his experiments, and five out of every six of the animals inoculated died.

Kitasato was the first to obtain pure cultures of the bacillus of tetanus. A patient having succumbed to the disease, he first inoculated pus from the wound into rabbits, and having obtained positive results, he proceeded as follows:—Some of the pus was inoculated into solidified blood serum and agar-agar, to which had been added two per cent. of grape-sugar. These cultures were kept at a temperature of 37° C. for twenty-four hours, when they were found to contain a number of micro-organisms, including the bacillus of tetanus, in small numbers, while on the following day the number had increased considerably. The tubes were then exposed to a temperature of 80° C. for about an hour in a water-bath in order to kill any other microbes present, and the contents inoculated into mice in which characteristic tetanus was induced. The spores remaining in the tubes were cultivated on plates, and also in closed vessels containing hydrogen, which were kept at a temperature of 20° C. A week later the plates were sterile, while colonies were visible in the hydrogen tubes, showing that the bacillus is anærobic.

The cultivations have a repulsive and penetrating odour, due to gas which is evolved during growth. They retain their virulence through successive generations, especially when mixed with sterilised earth.

The spores of the bacillus are very tenacious of life, although active growth is suspended below a temperature of 18° C.; they are able to withstand a temperature of 80° C. for from half an hour to an hour, but a moist heat of 100° C. destroys them in about five minutes. Ten hours' immersion in a five per cent. solution of carbolic acid does not impair their virulence, but they are killed in fifteen hours; a solution of corrosive sublimate (1 in 1,000) kills them in about thirty minutes, particularly if it be acidified.

The bacillus has the form of a slender rod, which, when actively growing usually presents a swollen and bulged extremity, due to the presence of a large terminal spore. The bacillus, which is motile, seems occasionally to multiply by fission, forming short chains. Staining reagents for the most part stain the rods, but leave the spores untouched.

When inoculated into solid nutrient media, growth commences below the surface, and as it increases and the bacilli gradually penetrate the mass of nutrient material, a fine feathery appearance is produced which is quite typical.

The telluric origin of tetanus has recently been investigated by Bassano in a series of experiments carried on at Marseilles. Six specimens of earth were obtained from dry localities which had not been contaminated with putrefactive or organic material for a long time, and used for the inoculation of twelve cobayes, but no results followed. Ten specimens of earth were then taken from cultivated land, meadows, or roads, and, each being inoculated upon two animals gave positive results. The inoculations were in each case made in the right flank at the level of the hind limb. Four of the animals died of septicæmia; the other sixteen all presented similar morbid phenomena as follows:—Rigidity of the limb adjacent to the seat of inoculation was observed two days after the inoculation, the limb becoming forcibly extended as this rigidity increased. By the third day the opposite limb was likewise extended, and the animal assumed and preserved the dorsal decubitus; then appeared trismus, and in the majority of cases extreme dyspnœa, which increased until death closed the scene, the fatal termination being not unfrequently preceded by violent convulsions. This gradual implication of successive parts of the body following on symptoms commencing in the neighbourhood of the inoculated spot is very typical, and throws light upon the action of the bacilli. As evidence that the resulting tetanus is really due to inoculation of a specimen of earth or a culture of the organism at the particular spot, the experience of other observers also is of considerable interest. Thus Lockwood states that a few hours (usually less than twenty-four) after the root of a mouse's tail has been inoculated with an appreciable quantity of pure culture, the tail becomes rigid, and either bent to one side or in a corkscrew fashion; the hind legs are next seized with spasms, and sometimes with tremors. The spasm becomes so intense that first one and then the other leg is extended, with the sole of the foot turned upwards; then the muscles of the trunk, of the fore-limbs, and of the neck and head become tetanic in definite order, those nearest the point of inoculation first, and afterwards those at a distance; and in about twenty-four hours the animal is dead. If the neck or fore-limbs be inoculated, instead of the root of the tail, the tetanus begins in them. The period of inoculation varies, being about twenty-four hours in the mouse, five days in rabbits, and from about four to sixteen days in the human subject.

Verneuil has expressed the opinion, to which he still firmly adheres, that tetanus is of equine origin. He accepts as proven that the disease is a product of a special micro-organism, and formulates, among others, the following conclusions: 'It is probable that several domestic animals are able to infect man, but satisfactory demonstration has been hitherto given only for solipeds. A wounded man can contract tetanus from the majority of neighbouring objects which may touch his wound, but observation and experience show that far the most dangerous objects are the horse with his immediate surroundings, then cultivated earth and some of its products; hence arises conflict between the equinist and the tellurist. Accord would be easy if, in accepting the deductions, one would subordinate the one to the other, and recognise that if earth is able to induce tetanus it does so because it is soiled by the tetanised horse.' He further argues that the disease is never spontaneous, but is always due to infection. His views have received great support in France, so much so that we find cases recorded because *no* contact with horses could be discovered. Other observers admit the power of cultivated soil to give rise to tetanus, but do not believe that this is due to horse-manure rather than to that of any other animal, as the ox or sheep, and they strongly oppose the equine origin of tetanus, not because such may not be its origin, but because they consider that this has not yet been proved to be the case.

The microbe of tetanus, like the vibrio of gangrenous septicæmia, may be innocuous in, and pass unchanged through, the alimentary canal of an herbivorous animal, and Sarmani, in Italy, has apparently discovered that such may be the case, not only in herbivorous but also in carnivorous animals, the micro-organism still keeping its infective power. Hence manure may become a potent source of tetanus dissemination. On the other hand, horses are unknown in the New Hebrides, yet tetanus is very common, but this, of course, is only negative evidence. In the case of two patients mentioned by Richelot affected with tetanus after ovariotomy, the disease appeared shortly after manure had been spread in the hospital court, thus suggesting also that air may be a vehicle for the transfer of virulent germs. Terillon also reports a case in which tetanus developed from a wound caused by a horse-shoe soiled with manure.

There cannot now be any reasonable doubt that the tetanus-producing bacillus is very widely distributed in the superficial layers of various kinds of soil, on the foul surface of streets, and in the dust of dwellings. Thus Bonone observed that out of seventy persons injured by the falling of a church during an earthquake, seven were attacked by tetanus. Animals inoculated with the dust of the church died of tetanus, although those inoculated with the dust of another church did not. Again, he observed that at the storming of the church in Bajaido, out of a similar number of injured persons nine died of tetanus, and in three he recognised the specific bacillus. He then experimented with dust taken from the ruins, and found that this, when inoculated into animals, produced the disease in them, the bacillus being also found in pus taken from the inoculated part.

Although it appears probable that tetanus is usually induced by direct inoculation with soil or other material containing Rosenbach's bacillus, the possibility of communicating the disease from one human being to another must be kept in mind, a case having been recorded where the accoucheur, being in attendance on a case of trismus, transmitted the disease to a woman in labour. A striking instance of apparent indirect transmission from one animal to another is related by Langer, in which all the horses castrated by the same *écraseur* died of tetanus, while after boiling the instrument in oil no others died or were affected from its use. Such cases, however, are rarely seen, and many observers deny the possibility of direct contagion altogether.

The influence of predisposition cannot be denied, and doubtless plays a principal part in the development of tetanus. Thus the negro race in particular, and those inhabiting hot climates generally, are believed to be more susceptible to the disease than dwellers in more temperate climates, and what is still more interesting is the observation that the natives of hot climates are far more liable to be attacked than Europeans resident there. In the American Civil War 3·1 per cent. of the cases occurred amongst the negro troops, who furnished only 2·7 per cent. of the total number of wounds. Tetanus is specially apt to occur in feeble and debilitated individuals, although the robust are by no means exempt, and it is most likely to occur, particularly in the case of wounds received on the field of battle, after sudden changes of weather, such as alternations from heat to cold, especially if associated with moisture of soil or air. Thus, in certain tropical climates, as in some of the West India Islands and amongst the marshes of Cayenne, it occurs with peculiar frequency, the most trifling scratches or punctures being followed by the disease. Macleod states that, after some of the Indian battles when the wounded lay exposed to cold nights after very hot days, tetanus was of very frequent occurrence. From these observations it seems

probable that the soil plays a double part in the ætiology of the disease; since it not only harbours the organism which is necessary for its production, but may also in certain instances directly predispose to the attacks of the bacillus by means of the amount of moisture it contains, or the amount of heat it is capable of absorbing and of radiating.

The relation of tetanus to soil is of such interest and importance that it may be well to add a brief record of some cases observed by Eiselberg which he had the opportunity of investigating thoroughly. The first is that of a woman in whom tetanus occurred after a compound fracture, the wound having been much contaminated with dirt. Like other observers, he found that neither cultures made from the blood nor inoculations of blood into animals produced any effect. He found, however, the typical bacillus in pus from the wound, and succeeded in transmitting the disease to animals by inoculations, both of the pus itself and of cultivations obtained from it, but he was unable to find bacilli in either blood or tissues. His second case was a very mild one, occurring in a man who had injured his finger, the wound being contaminated with dirt. Inoculation experiments, however, gave no results. In the third and fourth cases he was again successful in carrying on the disease through various animals—in the one, starting inoculations after the death of the patient from small pieces of skin removed from the edges of the wound, and in the other with earth from a cellar in which the injury was received. His fifth and sixth cases were both due to tetanus following on the running of splinters of wood into the hand, and in each instance the splinter, or portions of it, caused an attack of the disease in rabbits, when inserted beneath the skin, the bacillus being recognised in the secretion from the wounds thus caused.

In this connection it is interesting to note that the last four cases of tetanus that have been under treatment in the Norfolk and Norwich Hospital were all due to wounds caused by agricultural implements, such as a pitchfork and a scythe. Inoculation experiments, however, were of course out of the question, and unfortunately no search for the specific bacillus was made.

Anthrax

Malignant pustule or anthrax is a specific disease which is communicable to man, directly or indirectly from the lower animals; the herbivora being specially susceptible to it. It would appear that direct contagion from living animals affected with anthrax seldom or never happens, although butchers, slaughterers, and veterinary surgeons occasionally become infected in this way.

Under the name of woolsorters' disease, a form of anthrax has prevailed at Bradford and other places for many years, which is due to the handling and sorting of wool and hair obtained chiefly from Asia Minor, where anthrax disease is rampant. This method of communication, however, will not now be discussed, as a full account will be found in another section.

Anthrax appears to be specially prevalent in certain countries among animals pastured upon damp soils containing much humus, as, for instance, upon peat bogs, and near the borders of lakes and rivers that have overflowed; the hottest months of the year, particularly August and September, being those during which it is most frequent. Bollinger has suggested that dampness of soil may affect the prevalence of anthrax by affording conditions favourable for the growth and multiplication, apart from a living host, of the bacillus which is the cause of the disease. The bacilli, however, only exist in the soil when derived from a previous case of anthrax, either from the

excreta or discharges of a diseased animal, or from the dead bodies of those which have succumbed, and which have been carelessly buried or left to decay on the surface. Pasteur indeed is of opinion that when carcases of animals which have died from anthrax are buried, the development of bacilli into spores can take place in the soil, and that these spores may in turn be swallowed by earth-worms and be carried to the surface and deposited in their castings. In this way animals pastured on such soil would be liable to become infected. Koch and others strongly combat this view, and seeing that spores are only produced in presence of oxygen, it is quite probable that their formation would not take place, provided the animal be buried without being opened; but where this has been done for the purpose of investigating the cause of death, it would appear that the amount of oxygen in the pores of the soil may be sufficient to enable sporulation to come about. Schmidt Mühlheim has recently brought forward some experiments which bear somewhat on this point, as well as on the question of the anthrax bacillus producing spores in the meat of animals afflicted with this affection at the time they were slaughtered. He inoculated guinea-pigs with anthrax, and as soon as death took place they were skinned, and then the limbs were remove and placed in the incubator at a temperature of 39° C. The surface of the flesh was soon covered with a whitish film, which was found to consist exclusively of anthrax bacilli, in many of which commencing spore-formation was apparent. This vigorous growth did not, however, extend beneath the surface, as within the tissues there did not appear to be more bacilli than were found in portions of flesh which had not been placed in the incubator.

The immediate burial of the carcases of animals dying from anthrax has indeed been recommended as a preventive measure against further extension of the disease; since, if the skin be intact and the interment be performed at a sufficient distance beneath the surface, the spores which are more resistant do not put in an appearance, while the bacilli themselves apparently are destroyed after a varying period by putrefactive organisms, which being anærobic are capable of flourishing in absence of oxygen. But even supposing that Pasteur's theory cannot be looked upon as proved, it is evident that the soil may readily become infected from the discharges of moribund animals. The bacilli find sufficient pabulum in decaying animal and vegetable matter on the surface, and having free access of oxygen, spores are formed in them in abundance, by which in turn the herbage becomes contaminated. In the event of the meadows becoming flooded the spores may thus become carried over the adjoining land, and may even gain access to the drinking water, instances of infection of human beings having apparently been traced to such a source.

The Bacillus Anthracis

The specific organism of this disease is perhaps the one among those of a pathogenic nature, the morphological and biological characters of which have been most completely worked out. For this very reason, however, the subject will be found to be presented in so detailed a manner in the bacteriological section of this work that only the merest sketch will be attempted in this place. The bacillus was first discovered by Pollender in 1849, but Davaine was the first to maintain that this organism was the essential cause of anthrax in its various forms. The bacilli consist of straight, slightly bent, or curved rods, of comparatively large size, with square extremities; they often cohere by their ends, this being specially noticeable when they are cultivated artificially. Under these circumstances they may grow into long filaments in the interior of which bright granules appear.

These granules are spores, the appearance of which is of considerable

importance, seeing that they are much more resistant than the rods themselves, being able to withstand desiccation and a considerable amount of heat, while under favourable circumstances they are capable of again giving rise to the bacillary form. Spores only form when there is free access of air, but multiplication of the bacilli also takes place by a process of fission.

The possibility of attenuating the infecting power of pathogenic organisms was first established in the case of anthrax, it being found that these bacilli, which thrive best in an alkaline medium, become weakened when cultivated for about twenty days in a neutral nutrient fluid kept at a temperature somewhat higher than that of the body. Animals inoculated with such a culture pass, as Pasteur has shown, through a mild form of the disease, which protects against a second attack, more complete immunity being obtained by the subsequent inoculation of a more virulent material. The protection thus afforded appears, however, to last for a certain time only, when further treatment in a similar manner becomes necessary.

Klein has also shown that the virulence of the bacillus may be lowered by passing it through certain animals. Thus cattle and sheep may be protected for a time by inoculating them with the blood of mice which have been inoculated and killed with a virulent cultivation. On the other hand, a bacillus thus attenuated may once more be made to regain its virulence for sheep by first passing it through the system of a guinea-pig.

Hankin has recently announced a new method of creating immunity against anthrax by means of an albumose isolated from bouillon anthrax cultures, where it is formed as the result of the vital activity of the bacilli. This albumose is obtained by filtering the nutrient fluid through a Chamberland filter of unglazed porcelain to remove the micro-organisms and treating with absolute alcohol. He thus precipitates the albumose as a powder, which is redissolved for use.

By inoculation with this chemical material rabbits and guinea-pigs have been enabled to resist the action of virulent anthrax cultivations. More powerful still is an alkaloid which Sidney Martin has obtained, also from the nutrient material in which the bacilli have been grown, and it would appear more than likely that Koch's 'tuberculin' derived from cultivations of tubercle bacilli is in reality a solution of a somewhat similar substance. If this be so, it is not impossible that in the near future we may possess the power of preventing the incursions of numerous diseases, to which not only the lower animals but man also is liable, by means of a system of protective vaccinations of one and another chemical substance.

Cancer

There appears to be no doubt that the number of deaths from cancer, using this term as a general designation for all malignant new growths, is gradually increasing in number in this country year by year. The Report of the Registrar-General for 1889 shows that there were 18,654 deaths from this cause in that year, a number which is in the proportion of 643 to each million persons living, and which shows a further increase upon the ever-growing rates previously recorded. Some of this increase is most certainly to be attributed to increased accuracy in statement of cause of death, and to the system introduced some years back of writing for further information in cases where some vague cause, such as 'tumour,' has been given in the original death-certificate; a system which added, for instance, in the year under consideration no less than 421 deaths under the heading of cancer. Nevertheless, in face of the constant and great growth of mortality under this

heading, and the expressed belief of medical practitioners specially engaged in dealing with this class of diseases, that they are really becoming more and more common, it seems scarcely possible to maintain the optimistic view that the whole of the apparent increase can be explained as mere matter of registration ; and it must be admitted, as at any rate highly probable, that a real increase is taking place in the death-rate from these malignant affections.

Whether an inherited tendency, as distinct from influence of locality, have anything to do with the causation of neoplastic growths or not is a very difficult question; but it needs to be pointed out that neither a considerable proportion of cases with a family history of similar disease, nor even a considerable proportion of cases with a history of such affliction among the direct progenitors, is of itself sufficient evidence of inheritance. For seeing that one out of twenty-one males and one out of twelve women who reach the age of thirty-five die eventually of malignant disease, it follows by the law of probabilities that, on an average, in one of three cases either a parent or a grandparent will have died of such an affection. Supposing such parents and grandparents to have died after thirty-five years of age, and the proportion will be still higher if the circle of relatives be extended so as to include not only these direct progenitors, but collateral relatives, such as uncles and aunts. Seeing, however, that such a tendency if it exist would not, as a rule, manifest itself till after the usual age of marriage and parturition, it follows that the tendency would be likely to spread wider and wider among the population, there being no opportunity, as may occur in tubercular phthisis, of weeding out by early death from the candidates for matrimony those who are most seriously liable to this disease.

With regard to the part played by telluric and topographical conditions in the ætiology of cancer, Haviland states as his opinion that in countries having a high mortality from this disease the tributaries of rivers flow from soft, marshy, and easily disintegrated rocks into sheltered valleys through which the main rivers flow. During times of heavy rainfall these rains invariably flood the adjacent districts, and generally have their water coloured by alluvial matter in suspension. He further cites the Thames Valley as a typical cancer district in all these respects. From the statistics brought forward it would appear that, as is also the case with phthisis, cancer does not thrive on a high and dry soil; but this statement must be received with caution in connection with the fact that, although extensive drainage operations have been carried out in recent years, the death-rate from cancer does not show any corresponding decrease.

Such generalisations are, however, opposed by the fact that in Norway cancer occurs mostly in the mountainous districts and at considerable elevations, to some extent, no doubt, along the shores of the fjords, but least of all, as Hirsch has shown, on the open coast. Again, in Mexico the high tableland is more subject to cancer than the low plains. Obviously, therefore, Haviland's conclusions, even if true for the United Kingdom, are by no means universally applicable.

Calculus

In considering the connection of calculous disease with soil, it is important in the first place to see how the incidence of the disease is affected by geographical distribution, and then to ascertain, if possible, whether any common soil-condition can be found in those districts in which calculus is most prevalent.

The geographical distribution of calculus, or stone in the bladder, is a subject which has perhaps been better worked out than in the case of any

other disease. In all parts of the world calculous diseases are known, but in certain portions of the globe they are much more common than in others. This is notably the case in India, hardly any part of which is exempt, although the northernmost districts, particularly the North-West Provinces, are those which suffer most severely in this respect. Curiously enough, it is apparently only of recent years that the malady has become so prevalent in India, since Scott, writing in 1816, asserted that that country had the reputation of enjoying a special exemption from calculus.

In this country the evidence derived from hospital statistics, from death-registration and other sources, points to a special prevalence of the disease in the eastern and southern counties, while of these it is most common in Norfolk. The following table compiled by Cadge, of Norwich, from the death-returns for the five years 1867–71, giving the proportion of inhabitants in the several counties for each death from stone during that period, shows this fact very clearly :—

Deaths from Urinary Calculus in English Counties during Five Years

Eastern Counties	1 in 63,475 pop.	Southern Midlands	1 in 86,367 pop.
Norfolk	,, 42,744 ,,	Hunts	,, 59,137 ,,
Suffolk	,, 67,081 ,,	Bucks	,, 61,335 ,,
London	,, 70,099 ,,	Herts	,, 68,250 ,,
Wales and Monmouth	,, 77,202 ,,	Camb.	,, 69,845 ,,
Yorkshire	,, 77,520 ,,	Northampton	,, 82,525 ,,
West Riding	,, 61,405 ,,	Western Midlands	,, 128,216 ,,
N. and E. Riding and York	,, 71,475 ,,	Warwick	,, 65,670 ,,
South-Eastern Counties	,, 83,978 ,,	Shropshire	,, 66,750 ,,
Kent	,, 60,585 ,,	Worcester	,, 73,100 ,,
Sussex	,, 61,139 ,,	Stafford	,, 76,965 ,,
Berks	,, 93,470 ,,	Northern Counties	,, 191,875 ,,
Northern Midlands	,, 85,959 ,,	South-Western Counties	,, 203,985 ,,
Leicestershire	,, 64,115 ,,	North-Western Counties	,, 209,681 ,,

It is probable, however, that the local incidence of the disease in Norfolk is even greater than would appear from these statistics, since death returns have only a limited value in deciding this question, it being obvious that, where calculus is of frequent occurrence, operators will acquire more skill in its treatment, and consequently the number of deaths from operation or from non-relief of the condition will be relatively fewer. It should also be borne in mind that death statistics may be open to grave fallacy from errors of diagnosis made in referring death to this particular cause.

In Scotland the malady is for the most part somewhat more frequent than in England, and this appears to be still more the case if mortality statistics be taken for purposes of comparison. Cadge, however, has shown that this can in part be accounted for by the facts that not only are many less cases admitted into hospital in Scotland than in England, but also that the proportion operated on is much fewer than in this country, so that in this way the mortality from calculus is increased.

Curiously enough, Ireland, on the contrary, enjoys an almost complete immunity from the disease, and has done so for a lengthy period, as is shown from the earliest authentic statistics on the subject. Thus Yelloly, writing in 1845, states that, although he had inquired very thoroughly into the subject, he found that not a single case of operation for stone had occurred from first to last in the hospitals supplying the three and a half millions of people in Antrim, Armagh, Londonderry, Donegal, Fermanagh, Tyrone, Carlow, Kildare, Kilkenny, Longford, Louth, Wicklow, Clare, Kerry, Galway, Roscommon, Tipperary, and Mayo, and that no case had come to the knowledge

of practitioners among the poorer classes of the people in those counties. For the whole of the rest of the country the result of his investigations showed that the average number of operations was about six every year.

Other European countries enjoying a like immunity are Switzerland, Greece, and in the more northern districts of Norway, Sweden, and Denmark. Holland, on the other hand, has held the unenviable notoriety of supplying the largest number of cases of calculous disease in this part of the world. This fact comes out prominently in the surgical writings of the seventeenth and eighteenth centuries; and although the prevalence of the malady has decreased somewhat of recent years, Janssens states that it is still relatively common in Belgium.

Many of the earlier writers on this subject, from a comparison of those parts of Europe and England where the disease manifests itself to the largest extent, arrived at the conclusion that climatic influences likely to affect the soil, more particularly cold and damp, were of great ætiological importance in the production of the malady, Crosse, in his treatise on the formation of the urinary calculus, laying special stress on the cold and wet climate of Norfolk as accounting for the great frequency of stone in that county. The results of later investigations, however, do not support this theory. Thus Cadge shows that there are many parts of the North of Scotland as well as of Ireland where the climatic influences are the same, and yet there is none of the disease, and that in Norfolk itself stone is more frequent in inland parishes than in places on the coast which are least favourably situated as regards climate. In this connection it is also worthy of note that in many places where stone is endemic the areas affected are often very definitely bounded, so that the malady may be extremely rare in closely adjoining districts, although the conditions as regards climate are identical.

Again certain countries which have a decidedly wet and cold climate, such as Norway and Sweden, are practically exempt from the disease; while, on the other hand, it has been shown that Italy and Spain, for instance, and many parts of Southern Asia are eminently liable to calculus.

Another hypothesis which has received a considerable amount of support attributes the excessive prevalence of calculous diseases in certain districts to the hardness of the water which is used for drinking purposes by the inhabitants. Seeing that this will depend in turn on the nature of the soil from which the water is obtained, many observers have come to the conclusion that stone is more common on certain geological formations, and particularly where *chalk* is found in abundance. This theory, which has received the support of Sexton and others, who do not, however, believe that the water-supply has any causative influence on the disease, would certainly appear to be worthy of attention, although of late so many exceptions to the rule have come to light that it cannot now be considered to be of more than limited application.

The arguments both for and against this view are so well summarised by Hirsch that it may be well to quote his own words: ‘When we survey the distribution-area of the disease, we certainly discover an imposing array of facts that can be used in support of that doctrine, such as the prevalence of the disease on the calcareous and dolomite soil in the basins of the Don and Volga in Russia (to which Becketow has lately called attention), on the chalk soil of the eastern counties of England, and on the Jurassic limestone of the Swabian Alp in Würtemberg, beyond the limits of which, as on the Keuper of the Necker Valley, or on the Muschel Kalk (Triassic formation) of Franconia, the Spessart, and the Rhön, calculus is very unusual; further, in

some parts of Italy with a soil of limestone, such as the provinces of Brescia and Cremona, on the chalk and limestone of Syria, or the Jurassic limestone of Montreal, in a part of Maine with the same formation, and in Lexington, Ky., which stands on more recent limestone. But this geographical agreement of a number of centres of calculus, very striking though it be, loses no small part of its significance when we go further afield. We have to take into account, on the one hand, that the disease is indigenous to an equal extent on other kinds of soil, such as the basaltic trap formations in several parts of the Deccan, the basaltic and volcanic tufa in Mauritius and Réunion, the alluvium-covered granite of Canton, the transition rocks of North Wales, the carboniferous limestone of Yorkshire, the Zechstein of Altenberg, the red sandstone and variegated sandstone of the Rajestan States and other parts of Hindostan, the Keuper and Muschel Kalk of the plateau of Lorraine, and the clay soil of Reval and Ostend. On the other hand, we have to bear in mind that large territories belonging to the more recent limestone, chalk, or Jurassic formations are almost entirely exempt from the malady; such as the limestone coast-margin of Barbadoes and other West India Islands, the Jurassic formation of the whole of Western Switzerland and other parts of that country, and many parts of England.'

It is difficult also to see why, if there be some such common cause predisposing to the occurrence of stone in the bladder, the composition of the concretion should not in all cases be the same. No doubt, when once a stone has formed it may increase in size by the deposition of phosphatic layers, due to an ammoniacal state of the urine resulting from cystitis, particularly in elderly persons, who may not be able to thoroughly evacuate the bladder. Apart from this, however, we find that the composition of the nucleus varies in different parts of the world, even when the conditions of soil are the same. Thus Vandyke Carter states that the proportion of calculi with a uric acid or urate of ammonium nucleus in England is 72 per cent., while in India it is only 56; an oxalate of calcium nucleus, on the other hand, being more than twice as frequent in India as in England, a similar preponderance having also been found in Würtemberg and Moscow. It is possible that oxalate may in some cases develop from uratic calculi, but it is impossible to account for the frequency of their occurrence in certain localities in this way. Many suggestions have been brought forward, ascribing the differences to peculiarity of race, of constitution of diet, with exposure to prevalent easterly winds, and the like, but probably but little weight can be attached to any of these supposed factors, the exact ætiology of calculous disease having yet to be worked out.

Rickets

Many are the attempts that have been made to define a cause for this disease. Among those which have from time to time been suggested are prolonged suckling or, on the other hand, premature weaning; the effect of indigestible and insufficient food or of a deficiency in it of lime and of phosphoric acid. Experimental evidence has been invoked in support of these various theories, but the results have not been such as to give definite support to any one of them. All authorities are agreed that the morbid process is fundamentally a disorder of nutrition, a cause for which must probably be sought for either in an hereditary taint or in the manner of bringing up, defective or improper food, if it bear any import, acting, however, only indirectly by producing general weakness.

A noteworthy point to which attention has not perhaps been sufficiently directed comes out when we examine into the geographical distribution

of the disease. This is that, while in temperate regions it is moderately common, tropical and subtropical countries are almost free from it, particularly in its severer forms. There is, in fact, abundant evidence that, both in amount and severity of type, the disease stands in a definite relation to climate, and that, as Hirsch has stated, countries with a cold and wet climate, subject to frequent changes in weather, such as Holland, many parts of England, the North German plain, the mountainous regions of Central and Southern Germany, and the plains and mountainous districts of Northern Italy, if they are not the exclusive seat of rickets, are at all events its head-quarters. It would appear, moreover, that of the districts mentioned the disease is more prevalent wherever the character of the climate is specially dependent on the nature of the soil; as, for instance, in the neighbourhood of marshy plains or in valleys which are deep and damp and liable to frequent floods.

Oppenheim, indeed, arguing from this preference exhibited by the disease for wet and marshy districts, and from the fact that enlargement of the spleen is not unfrequently found in rickety children, has been led to the conclusion that the disease is in some way related to a malarial taint. There is, however, little or nothing to be found in support of this view, and, indeed, it would appear that in some instances at any rate rickets is least common just in those very districts where malaria is worst.

On the other hand, rickets is of rare occurrence at elevated sites, particularly where the soil is also dry, even though at the same time the hygienic conditions among which the population live may be the reverse of favourable. From a consideration of these observations it would appear, then, that a line of treatment which might be expected to be attended with beneficial results would consist in the removal of children subject to this disease to a warmer and drier climate for a time. Unfortunately in the majority of cases, such a complete change is usually impossible, and recourse must therefore be had to care in feeding, combined with warm clothing, exercise in the open air, and medical treatment of a more or less empirical kind.

Goitre and Cretinism

Although these diseases, and more particularly goitre, occur in widely different portions of the globe, it is a remarkable fact that in each locality when they are endemic the incidence is mainly on a small circumscribed tract of country, the surrounding districts being often completely free. There is, then, an intimate relation of these diseases to locality, and probably therefore to the nature of the soil or the soil contents, Klebs having shown that atmospheric influences, such as the amount of sunlight, air, and so on, play but a subordinate part in the matter, as if otherwise these affections would not be so limited to particular spots as is invariably the case.

It is, moreover, a well-recognised fact that healthy persons coming into goitrous districts from places where the disease is unknown not unfrequently contract the malady, sometimes after a very short stay only; while, on the other hand, removal from goitrous centres has been found to have an influence for good, either in preventing the occurrence or in arresting the further development of the disease. A further not unimportant point is found in the occurrence of goitre among domestic animals, such as horses, mules, goats, sheep, pigs, cats, and dogs; a fact which was known to Pliny, and which has been amply substantiated by numerous observers since his day.

What are the precise conditions of soil common to all the various centres of goitre and cretinism, and which are concerned in the production of these

nearly related diseases, is, however, an exceedingly difficult question. Certain it is, at any rate, that the degree of elevation, or the configuration of the ground, has no influence as an ætiological factor, seeing that, although perhaps mountainous districts are more frequently affected than lower lying tracts of country, and that in coast regions goitre is apparently unknown, nothing further can be definitely stated in this respect which can be shown to be of universal application with regard to the various situations in which goitre is known to occur. The same remarks will apply to the theory first propounded by Saussure, and which has received a certain amount of support, namely, that the spots of greatest intensity are to be found in deep dark valleys, where soil and air alike are damp, since innumerable instances could be adduced of wide tracts of level country which suffer to quite a similar extent, even where the soil is of the driest. A wet or marshy soil will be likely to be prejudicial to the health of those living upon it, and, therefore, it is likely that a change for the better in this respect may become apparent after the effectual drying of the soil by subsoil drainage and the like. In this manner, no doubt, may be explained the decrease in the amount of goitrous disease which has occurred of late in certain situations which formerly were more subject to it than at present, the improved hygienic conditions by improving the health of the population having rendered them less liable to the incursions of the disease.

We are thus brought back to the conclusion that there must be some connection between the geological and mineralogical character of the soil and the endemic occurrence of these affections, but the discrepancies of opinion between the various observers who have investigated the subject afford but little ground for the foundation of anything like a dogmatic assertion on the subject. As a matter of fact, it would appear that sufficient care has not been bestowed on the determination of the true geological conditions of the particular localities under consideration, especially as it would be necessary to investigate not only the characters of the upper layer of the soil, but of the subjacent strata also, since not only may they be very different from the surface soil above, but they may influence, to a much greater extent, the composition both of the air and water of the district.

A view that has much to be said in its favour, and which, down to the present day, has been accepted by many observers, is that which supposes that the use of water containing certain mineral constituents in considerable quantity plays the chief part in the genesis of goitre. Thus in many parts of the world, so-called 'goitre springs' are to be found which have the popular reputation of causing the appearance of the disease in those who drink of them; and so firmly rooted is the belief that there are numerous records of malingering, especially soldiers desirous of escaping active service, having taken the water with the hope of inducing an attack.

As to the exact nature of the ingredients of the water which would appear to possess this power for ill, there is great diversity of opinion, but seeing that the nature of the water must in time depend on that of the soil from which it springs, or over which it flows, it might be supposed that careful examination of the constituents of the soil in affected areas might enable us to decide the point; unfortunately up to the present no such successful result has been obtained. Many suspected goitre springs contain a large amount of carbonate of calcium or gypsum dissolved in the water, and thus the idea arose that endemic centres of goitre were to be sought for in places where there was a limestone soil. On attempting to put this theory to the proof accurate examination of the soil has undoubtedly furnished a considerable amount of corroborative evidence on the point. Thus McClelland, who

instituted a most thorough inquiry into the subject in the provinces of Kumaon, on the slope of the Himalaya, records the result as follows:—

'In ninety-one villages situated on granite and gneiss, hornblende slate and mica slate, clay slate, green sandstone, granitine, and silicious sandstone, having an aggregate population of 5,383, there were twenty-nine goitrous persons and no cretins; whereas in thirty-five villages, on Alpine limestone (i.e. Jurassic limestone and Zechstein), having an aggregate population of 1,160—390 cases of goitre were found and thirty-four of cretinism.' These statistics have received support from Billiet and others, who asserted that in numerous instances in which adjoining districts were found to show a striking difference in the extent to which goitre was prevalent the state of the soil was obviously the determining factor in the one direction or the other, seeing that apparently an affected district might, in all other respects, be under absolutely similar conditions to an adjacent spot where the disease was unknown.

A more extended series of observations soon showed, however, that this theory required modification, and the balance of opinion veered round to the hypothesis, originally put forward by Zambroin in 1825, and later brought into notice independently by Grange, that the question did not depend on the presence of limestone itself so much as on the amount of magnesium salts combined with it, goitre being found to the maximum extent in persons living on a soil of magnesian limestone or dolomite. 'However various the elevation, the configuration, and the formations' of the regions investigated 'might be, an unvarying factor in them all was the presence of magnesia in the rock, whether it occurred in the form of magnesia containing silicates (as particularly in gneiss and granite and hornblende rocks) or in the form of dolomite; and it was the absence, or the somewhat scanty or infrequent occurrence, of magnesia in the younger Jurassic rocks, in the chalk, and on the Tertiary formations that explained the immunity of localities in the soil of which these predominated.'

Striking as is the manner in which this theory, so ably developed by Grange, fits in with the results of observation in various parts of the world most widely separated from one another, such as Central Europe, Oudh, and Brazil, it is evident that it cannot be considered as by any means of universal application. Thus Thomson and others have called attention to the fact that, although in New Zealand large masses of magnesian limestone lie exposed in the Northern Island, where live by far the greater part of the native population, goitre is a disease entirely unknown among them.

Yet another theory, apparently, however, more untenable than the older ones it challenges, is due to Saint Lager, who, as the result of a most comprehensive study of the geological characters of the soil in all parts of the world, as far as they could be ascertained, came to the conclusion that the results of former observers as to the importance of the presence of magnesia was capable of explanation in another manner. According to his view, goitre or cretinism is prevalent in those districts only where there is an amount of metal-yielding rock to be found, the undoubted connection traced by others between the extent of the disease and the amount of magnesia in the soil being due, in his opinion, to the fact that limestone rock frequently contains sulphide of iron. Iron, however, is not the only metal producing this result, as the presence of copper pyrites might, he believed, produce a similar effect.

From what has already been stated it will be seen how various are the different theories that have been brought forward to account for the special prevalence of goitrous diseases in certain localities, but at the same time it

is noteworthy that without exception they all agree in referring such endemicity to conditions of the soil, although at this point agreement ceases, so that the problem must be looked upon as one which still awaits solution. It appears certain, however, that whether or not the presence of magnesium salts in the soil in any way predisposes to diseases of this kind, it is extremely unlikely that the result is brought about through the medium of drinking water which has been rendered hard by an abnormal quantity of such salts.

EXAMINATION OF SOIL

Physical and Chemical Examination of Soil

From one point of view the soil may be considered as a mass of particles of matter having certain physical properties which will depend on the relative size of the particles of which it is composed, on the density with which they are packed together, on their power of absorbing and retaining water, and on the friability of the mass.

Surface or subsoil can be mechanically analysed either by removing a block of a certain size, for instance a cube of about six inches, or by taking a known weight (100 grammes), which after being dried and broken up by the hands is passed through a series of sieves. In this way the stones may be separated according to their various sizes by the sieves of larger and smaller mesh until fine particles only are left. These again may be separated still further by mixing thoroughly with water, and then when the coarser particles have subsided, pouring off the supernatant fluid containing suspended matter, which consists, for the most part, of silicate of aluminium. This part of the process is more accurately carried out by the use of Noebel's apparatus, which subdivides the finer matter into four or more grades.

Such a mechanical analysis is, however, of comparatively little importance, except in so much as it makes a distinction between the silica which exists as sand and that which is present as clay; a distinction which is not shown in an ordinary chemical analysis, in which both kinds of silica would be classed together. Should the soil consist almost entirely of *clay*, it will dry into a hard mass, which it may be extremely difficult to break up with the hands alone; if, however, it constitutes what is called *loam*, though still drying into lumps, it will break up more readily than true clay owing to an admixture of sand or lime. If this latter substance be present in considerable amount, the term *calcareous* will be applied to the soil. The presence of lime in the soil is easily detected by adding a few drops of hydrochloric acid, which by disengaging carbonic acid gas from the carbonate, the form in which lime usually occurs, causes effervescence. The extent and duration of this give an approximate idea as to the amount of lime present.

By such a simple examination of soil a considerable amount of information may be obtained which is of importance from a hygienic standpoint, but when possible this should be supplemented by a more extended *chemical* examination. The various constituents of the soil may obviously be somewhat numerous, but of these a certain number are *extremely* rare, and for most purposes it suffices if a determination of the following substances be made—viz. silica, alumina, lime, magnesia, chlorine, sulphuric and nitric acids, carbon and nitrogen. Of these, the two latter exist for the most part in combination in the *organic* constituents, although, as has been mentioned carbonic acid is also present in the free state in the interstices of the soil.

Certain of these constituents or compounds of them are not soluble in

water, although they are capable of being taken up by plants. Such is the case, to a considerable extent, with phosphoric acid in the soil. The fact has been demonstrated that when the roots of plants come in contact with a stone slight indentations will be produced which have evidently been eaten away during the growth of the roots. This is accomplished by means of the extremely thin membranes of the root-hair being permeated by an acid juice which coming in contact with the surfaces of the particles of soil renders soluble the molecules of nutrient materials adhering there; it thus becomes possible for these substances to penetrate into the root-hairs according to the laws of diffusion, and thence to pass over into the stream of sap to be carried finally to the organs of assimilation. Sachs has shown experimentally that roots which become closely applied to the polished surfaces of marble plates corrode them so that after a time a corrosion figure of the roots is obtained on the marble surface. Consequently it is usual in agricultural chemistry to estimate the composition of such portions of the soil as are soluble in water and in hydrochloric acid respectively, the former portion being regarded as that which is capable of immediate utilisation by plants, while the latter insoluble portion is looked upon as a reserve fund which may be utilised in the future.

In order to estimate the amount of organic matter in the soil a known quantity is weighed after careful drying, heated to redness, and then reweighed, the loss of weight representing the organic matter which was present. A possible fallacy must, however, be borne in mind in conducting this process, particularly when a clay soil is being examined, seeing that in such a case a considerable amount of the loss of weight which occurs on heating will be due, not to organic matter, but to water of combination, which is not driven off unless the temperature be raised above that of boiling water.

Owing to this fact the amount of organic matter present in clay soils has been supposed to be as much as from 10 to 12 per cent., which is obviously erroneous.

The portion which remains after the organic constituents have been dissipated by the effect of heat consists of the inorganic or mineral constituents.

The substances soluble in water consist for the most part of chlorides, sulphates, and nitrates, while the greater part of the magnesia, lime, alumina, and iron are insoluble. It is important to determine the extent to which the constituents of a given soil are thus soluble, so as to obtain an indication as to whether drinking water obtained from such a soil is liable to be injuriously affected. For this purpose 10 grammes are to be thoroughly shaken with distilled water. Filter; evaporate the filtrate, weigh, and incinerate. The loss of weight after incineration will indicate organic matter, together with varying amounts of water of combination and of ammonia; Way having shown that the absorbent property of clay particularly enables a soil to retain such an amount of ammonia in the soil as to exert a very important purifying influence upon water impregnated with organic and other substances, which find their way slowly through the soil. Dissolve the residue again in water and examine for chlorine, sulphuric acid, lime, alumina, iron, and nitric acid. (A description of the necessary methods will be found in the section on WATER.)

To the portion insoluble in water add pure hydrochloric acid after previous evaporation. Or, more accurately, (1) take 40 grammes of a fresh portion of the soil and to it add 30 c.c. of hydrochloric acid and heat, noting whether effervescence takes place. Add 100 c.c. of distilled water and digest for about twelve hours. Filter; dry and weigh the residue.

(2) To the acid solution add ammonia, which will precipitate oxide of iron and alumina. Filter; dry and weigh the precipitate.

(3) To the filtrate add ammonium oxalate. Filter; dry; wash and burn the calcium oxalate and weigh the calcium carbonate produced.

(4) To the filtrate from (3) add sodium phosphate. Collect the precipitate; dry and weigh. Every 100 parts represents seventy-nine parts of magnesium carbonate.

(5) The residue remaining after treatment with hydrochloric acid consists of clay, quartz, and silicates of aluminium, iron calcium, and magnesium. Fuse with three times its weight of sodium carbonate and then heat with dilute hydrochloric acid. Iron, lime, alumina, and magnesia will enter into solution, silica remaining undissolved. Filter; dry and weigh the insoluble residue.

(6) Evaporate the filtrate from (5) to dryness. Moisten the residue with a concentrated solution of ammonium nitrate and heat on the water-bath until the evolution of ammonia ceases. Add hot water, filter, wash the alumina and ferric oxide; dry, ignite and weigh.[1] The mixed oxides should now be heated in a porcelain boat for about half an hour, while a stream of dry hydrogen or coal gas is passed over them. To the mixture of alumina and reduced iron add a $2\frac{1}{2}$ per cent. solution of nitric acid in distilled water; warm, filter, precipitate the ferric oxide by ammonia, wash, dry and weigh it. By deducting the weight of ferric oxide from that of the mixed oxides the quantity of alumina is obtained.

The iron may also be estimated by heating the mixture of alumina and ferric oxide with dilute sulphuric acid, filtering, reducing with a small piece of zinc, and titrating with a standard solution of potassium permanganate.

This method of estimating Fe depends on the fact that $KMnO_4$, added to a solution of a ferrous salt, oxidises it to the ferric state.

The reaction is :

$$10FeSO_4 + 2KMnO_4 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + K_2SO_4 + 2MnSO_4 + 8H_2O$$

The ferrous solution, prepared as above directed, is made up to bulk with cold distilled water in a 250 c.c. flask, and 50 c.c. of this solution are transferred to a beaker containing 200 c.c. of air-free water standing on a sheet of white paper. Now run in the standard permanganate from a Mohr's burette, provided with a glass stopper, little by little, and with constant stirring: as the $KMnO_4$ falls into the solution of ferrous salt a pink blush is formed, but disappears on stirring as long as there is any ferrous salt unoxidised to ferric. As soon as all is converted into ferric, the pink colouration is permanent, and this is the end of the reaction. Read off the number of c.c. needed to effect this, and repeat with two more successive quantities of 50 c.c. of the ferrous solution, and take the mean of the three results as a basis for calculation. The permanganate solution requires standardising from time to time; the method of doing this and the preparation and standardisation of the permanganate solution in the first instance are well given in Thorpe's 'Quantitative Analysis,' p. 148.

Calculation :

Let x = number of c.c. $KMnO_4$ used,
y = weight of Fe in grammes oxidised by 1 c.c. $KMnO_4$;
$\therefore xy$ = ,, ,, ,, ,, x ,,
i.e. xy = ,, ,, in grammes in 50 c.c. solution;
$\therefore 5xy$ = Fe in 250 c.c. or in mixture of Fe and Al from (6).

[1] For the total aluminium and iron the results of (2) should be added to the residue thus obtained.

Appended are some complete analyses of surface soils which give a fair idea of the manner in which they differ from one another in composition :—

Complete Analyses of Soils (Lloyd)

—	No. I.	No. II.	No. III.	No. IV.	No. V.	No. V. 18 to 27 in. deep
*Organic matter and water of combination	5·033	6·344	4·200	8·858	3·450	1·550
Oxide of iron	5·200	5·312	3·659	6·350	4·001	3·201
Alumina	3·400	4·560	4·100	3·430	·649	·440
Lime	1·360	3·312	·670	·484	·431	·151
Magnesia	·400	·432	·266	·466	·225	·201
Potassium oxide	·365	·468	·320	·333	·282	·253
Sodium oxide	·121	·179	·031	·092	·069	·023
Phosphoric acid	·141	·204	·141	·217	·217	·141
Carbonic acid	·875	1·640	·380	—	—	—
Sulphuric acid	·060	·109	·061	·137	·130	·089
Nitric acid	·001	·001	·001	·002	·008	·002
Chlorine	·005	·011	·002	·005	·007	·004
†Insoluble silicates and sand	83·066	77·401	86·232	79·733	90·675	93·925
	100·027	99·973	100·063	100·107	100·144	99·989
†Consisting of oxide of iron	1·827	1·625	·763	1·594	1·995	2·723
Alumina	6·188	4·489	6·607	1·897		
Lime	·511	·774	·638	·558	·553	·732
Magnesia	·388	·332	·167	·223	·126	·131
Potash	·424	·578	·182	·358	·399	·197
Soda	·920	·534	·304	1·012	1·242	·779
Silica	72·848	69·273	77·626	74·091	86·360	89·363
	83·106	77·545	86·287	79·733	90·675	93·925
*Containing nitrogen	·170	·107	·141	·254	·101	·050

In the first three specimens of soil which were analysed by Dr. Voelcker there was a considerable amount of clay, they being what are termed 'stiff' soils, while No. IV. is a loamy soil from Bedfordshire, and No. V. a light sandy or gravelly soil. The sixth table shows an analysis of the subsoil lying beneath No. V., and it is obvious that it contains far less soluble constituents than the surface layer above.

Bacteriological Examination of Soil

The number of bacteria which may be found in mould or surface soil is usually very large, although pathogenic organisms are comparatively rare, except perhaps in the filth-laden soil of crowded and insanitary districts. Certain forms, indeed, are distinctly beneficial, since by their life processes oxidation (nitrification) of nitrogenous organic matters in the soil is brought about, while other forms, as agents of putrefaction and fermentation, play a very important part in the economy of nature.

It will be obvious, therefore, that the mere presence of even considerable numbers of micro-organisms in a sample of earth does not of necessity show that there is danger to health in building on or even in obtaining water from the locality from which it is taken, and therefore the mere enumeration of the number of colonies which can be grown on a nutrient medium from a given weight of earth is a very fallacious test.

In addition, the various colonies must be isolated and sown on media of various kinds, and methods of staining, and even of experimental inoculation,

would require to be carried out before it can be definitely asserted that anything of a pathogenic nature is present or not. It is, of course, impossible that such an examination can in every case be carried out in its entirety, and therefore we are thrown back on the use of the ordinary microzyme test, the only use of which is in enabling us to judge of the approximate number of micro-organisms present, and not in forming an opinion as to whether the soil is of such a nature as would be likely to harbour organisms of a dangerous nature.

For the purpose of obtaining a cultivation of the micro-organisms in soil there are various modes of procedure. Either the ground air aspirated from different depths (as in the method used by Lewis and Cunningham for the estimation of the carbonic acid) may be drawn over the surface of nutrient gelatine, or samples of the soil itself may be examined. This, which is the simpler method, is carried out as follows :—

A sample of earth is first dried, then finely powdered and shaken up in a test tube of sterilised water, a drop of this being afterwards transferred to another tube of peptone-broth or gelatine. Again a small quantity of the earth may be sprinkled directly over the surface of nutrient gelatine prepared for a plate cultivation. The best method of all, however, probably consists in taking a carefully weighed amount of dried and pulverised earth and adding it to a test tube of gelatine, which has been previously rendered fluid by heat. By shaking it is distributed as evenly as possible through the medium, which is then poured out over the surface of a carefully levelled glass plate, on which it gradually sets into a solid film. If the plate has been previously divided up into squares by carefully ruled lines cut on the under surface of the glass, it is very easy to count the number of colonies which develop in a given area, and so by counting the squares to calculate the number of bacteria that were originally present in the given sample of earth. These colonies become noticeable after a few days' growth, when the various species, owing to the difference in their mode of growth, will form clusters varying in size, aspect, and arrangement. As Klein has shown, however, it must be borne in mind that the number of colonies is no absolute index of the number of bacteria in the soil for the following reasons: (*a*) not every colony that makes its appearance on the plate cultivation—even granted that it is due to the growth of a single species, which is not invariably the case—owes its origin to one single individual, since, for instance, micrococci, bacteria, and bacilli may occur in the original sample as zoöglea and chains, and these cannot by any amount of shaking be broken up into single elements; (*b*) not all bacteria introduced into the gelatine come up as colonies, since not all of them are capable of growing in the gelatine, and not all of them can thrive at the temperature at which the gelatine remains solid; (*c*) the liquefaction of the gelatine by some of the colonies and not by others does not necessarily indicate different species, since this depends sometimes on the nature of the nutrient gelatine, and to the fact whether the growth takes place in the depth or on the surface; (*d*) accidental contamination with organisms of the air during the preparation of the plate cultivation cannot be prevented, and if the air happens to contain a good many organisms, as would be likely to be the case in an ordinary laboratory, for instance, the total number of colonies appearing in the plate cultivation may exceed the number of bacteria present in the sample of earth which was being tested.

There are certain pathogenic organisms which have so typical a mode of growth, as is the case with the anthrax bacillus, which has been proved by Pasteur to be capable of existing in the soil, that their presence or absence

may be detected by simple examination of the cultivation, but, as stated above, this will usually not be the case.

In a similar manner to that already described, the dust which settles from the air in houses and hospitals or other public buildings may be distributed over the surface or in the substance of nutrient gelatine, and thus the micro-organisms which develop may be studied both as regards their morphological and biological characteristics.

FOOD

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FOOD

By *food* we mean the substances taken into the body which are utilised in maintaining the functional activity of the organism. By means of food during adolescence, growth is maintained, and in adult life the body-weight remains at a healthy level, or increases in particular conditions, the temperature is maintained, and muscular effort is made possible. The importance of the scientific study of food and of dietetics from a hygienic standpoint cannot therefore be overestimated. The definition just given would necessarily include under the heading Food the oxygen taken into the body by means of the lungs; and, strictly speaking, oxygen *is* a food, and one of the most important. The taking in of oxygen is, however, unlike that of food, in the main an involuntary act; so that the term 'food' is limited to substances taken by the mouth into the digestive tract, where, for the most part, they undergo changes preparatory to entering the tissues of the organism—preparatory to assimilation, as the process is termed.

The Proximate Principles of Food, or Foodstuffs

are the substances which constitute food. They may be classified as follows:—

- I. *Organic*
  - 1. Nitrogenous, as proteids or albuminoids.
  - 2. Non-nitrogenous
    - (*a*) Fats.
    - (*b*) Carbohydrates.
    - (*c*) Vegetable acids.
- II. *Inorganic*
  - 1. Mineral salts.
  - 2. Water.
- III. *Food-accessories*, such as tea, coffee, alcohol, creatin, &c.

The first two classes of foodstuffs are essential to life; but in the food of man there is a third class of what may be called 'food-accessories,' which hold an important position in dietetics. They are flavouring agents, stimulants, &c., and are well expressed by their German name, 'Genussmittel.'

Nitrogenous Foodstuffs

The greater part of the solid constituents of the tissues of the body (with the exception of bone) consists of abuminous or proteid substances; the liquids of the body also contain them in solution, not only the blood and the lymph, but also the interstitial liquid of the tissues, which is really a form of lymph. A certain amount of nitrogen in the form of urea (30 to 40 grammes or 500 grains daily), and of uric acid (0·5 gramme or 7 to 10 grains daily), with a few other nitrogenous bodies in small amount, is daily excreted in the urine. These nitrogenous bodies are formed from the destruction (oxidation) of the proteids of the body; the nitrogen they contain is a loss to the body, and to repair this loss a daily intake of nitrogenous food is necessary. By this means the nitrogen-equilibrium of the body is

maintained—that is, the relation between the intake and output of nitrogen. The equilibrium is, however, not perfect, since the sum of the nitrogen passed in the urine and fæces is less than that taken into the system. The only form of nitrogen which the body can assimilate is that of proteid or albuminous substances. The plant builds up its proteids from the nitrates and ammonia of the soil, but the animal cannot do this: it utilises the proteids originally synthetised by the plant.

Proteids are composed of carbon, hydrogen, nitrogen, and oxygen; they all contain sulphur, and some contain phosphorus. Their chemical constitution (and so their molecular weight) is unknown; but although there are individual differences of composition, especially between animal and vegetable proteids, their average percentage composition may be stated as follows (Hoppe-Seyler):—

	O	H	N	C	S
From . .	20·9	6·9	15·2	51·5	0·3
To . . .	23·5	7·3	17·0	54·5	2·0

Thus more than half of a given weight of proteid bodies is composed of carbon, while they contain about 16 per cent. of nitrogen. The proteids taken in as food are derived both from animals and plants; and, as far as is at present known, there is no difference in nutritive value between the proteids from these two sources. Considered as food, they may be divided into two groups: one, true proteids, the members of which are of equal nutritive value, and are capable of sustaining the N-equilibrium of the body; the other, albuminoids, which are not equal in nutritive value to the first group, and are not capable of performing completely the functions of proteid food.

This second group contains substances obtained only from animals—such as *gelatin* (*ossein*[1]), *chondrin*, and *keratin*. Gelatin, the only important member of this group, contains a larger percentage of nitrogen than the ordinary proteids—viz. from 17·8 to 18·8 per cent.; it differs also in some chemical reactions, and does not, like most proteids, yield tyrosin on decomposition.

The first group of proteid foods are the most important; they may be divided into—

1. *Globulins.*—The myosin of muscle, the globulin of the serum of the blood, those contained in the white and yolk of eggs, are examples from the animal kingdom, while from the vegetable kingdom are the globulins contained in the seeds of Leguminosæ and of the cereals.

2. *Albumins.*—The albumin of the serum, and egg-albumin.

3. *Insoluble Proteids.*[2]—The fibrin of the blood and the gluten of wheat.

These three classes have one common characteristic, they are coagulated by heat; when coagulated, as in the process of cooking, they are insoluble in water and dilute acids or alkalies, but are readily digested and rendered soluble by the gastric and pancreatic juices (pepsin or trypsin).

4. *Albumoses.*—These are closely related to peptones, and are found in the cereals, and are taken as food in wheaten flour, rye, rice, and barley. They are probably widely distributed in the vegetable kingdom, and are formed by pepsin from the ordinary proteids of foods (Classes 1 to 3). These animal albumoses are often administered in partially digested foods to invalids: they are the precursors of *peptones*, which also belong to this class of proteids.

5. A fifth class of food-proteids includes the casein of milk, and the legu-

[1] There is practically no difference between ossein and gelatin (Schützenberger).

[2] That is, those insoluble in water and in saline solutions at ordinary temperatures.

min[1] and conglutin of peas, beans, &c. (Leguminosæ). Classes 4 and 5 have the common characteristic of not being precipitated, and thus not coagulated, by boiling their solutions. The albumoses and peptones do not require so complete a digestion as the casein of milk.

As an appendix to Class 5 may be mentioned *syntonin* or *acid albumin*, which exists in some foods (e.g. meat) and *alkali albumin*: these are formed by the action of dilute acids and alkalies on ordinary proteids, and are not precipitated from solution by boiling.

Non-nitrogenous Organic Foodstuffs

These are *fats* and *carbohydrates*.

Fats.—In the majority of diets used by different nations, fat is an added constituent. It is absorbed by the body chiefly in the form of neutral fat, but also in the form of fatty acids and of their compounds, alkaline soaps. The neutral fat taken as food always contains free fatty acids in greater or less proportion, and in some foods (*e.g.* cheese) the fatty acids are in large proportion.

Fats are compounds of the triatomic alcohol glycerine, $C_3H_5(OH)_3$, and fatty acids. These fatty acids belong to two series: 1, monobasic acids, of the general formula $C_nH_{2n-1}O(OH)$, such as palmitic acid, $C_{16}H_{32}O_2$, and stearic acid, $C_{18}H_{36}O_2$. The fats formed are called *palmitin* and *stearin*, both solid compounds. 2. Acids of the acrylic acid series, with the general formula $C_nH_{2n-3}O(OH)$, such as oleic acid, $C_{18}H_{34}O_2$. *Olein* is a liquid fat.

All fats contain carbon, hydrogen, and oxygen, and differ from carbohydrates in the fact that the oxygen is proportionately less than will form water (H_2O) with the hydrogen contained in the molecule. In food there is a mixture of neutral fats with free fatty acids; the solid fats are generally mixed with olein. (For fats present in different foods, see separate accounts of articles of diet.)

Carbohydrates are derived chiefly from vegetable foods, and are mostly taken as food in the form of starch. They all contain carbon, hydrogen, and oxygen, the hydrogen and oxygen being in the proportion to form water.

1. The group of *glucoses* $(C_6H_{12}O_6)_n$ consists of three forms; (*a*) *grape-sugar* (dextrose, glucose), (*b*) galactose, a product of milk-sugar, and (*c*) *lævulose* (invert-sugar), which is contained in the juices of plants and in honey; (*d*) *inosite*, isomeric with grape-sugar, and found in muscle and some other animal foods, and in beans and the juice of the grape.

2. A second group differs from the first group in containing one molecule of water less than the double molecule of glucose; thus $2(C_6H_{12}O_6)-H_2O = C_{12}H_{22}O_{11}$. To this group belong (*a*) *milk-sugar* or lactose, occurring in milk; (*b*) *maltose*, which is the end-product of the digestion of starch in the digestive tract; (*c*) *saccharose* or cane-sugar, occurring in many plants, as the sugar-cane and the beet.

3. A third group contains bodies with the formula $(C_6H_{10}O_5)_n$, and are related to members of the second group by considering them as containing one molecule less of water. Thus milk-sugar, $C_{12}H_{22}O_{11} - H_2O =$ starch, $2(C_6H_{10}O_5)$. To this group belong (*a*) *glycogen* ('animal starch'), found in certain articles of diet, such as liver and molluscs; (*b*) *dextrine*, associated with starch in many foods and formed from starch in the digestive tract;

[1] It is probable that legumin and conglutin are not really 'vegetable caseins,' but are artificial products, the alkali used in their extraction transforming the globulin present (Vines). The proteids of vegetable foods require complete reinvestigation.

(c) amylum or *starch*, found in vegetable cells; (d) *cellulose*. This last, although of no great value as food to man, is of value to herbivorous animals. The presence, however, of indigestible cellulose in the food of man has an effect, as will be pointed out, on the complete digestion and absorption of digestible foods.

Vegetable Acids

These are grouped together, although they belong to different chemical groups, because they perform the same physiological function: their salts are converted into carbonates in the body, and thus preserve the alkalinity of the blood, tissues, and secretions (e.g. pancreatic juice).

Acetic acid, $C_2H_4O_2$, and *lactic acid* (oxypropionic acid), $C_3H_6O_3$, belong to this group: they are related to fatty acids, but in their function as food differ greatly from fatty acids.

The other acids belonging to this group are also allied to the fatty acid series: *oxalic acid*, $H_2C_2O_4$; *tartaric acid*, $C_4H_6O_6$ (dioxysuccinic acid); *citric acid*, $C_6H_8O_7$; *malic acid*, $C_4H_6O_5$ (oxysuccinic acid). This group differs from the first in the fact that they have an excess of oxygen in their composition—more O than will form water with the H they contain.

The most important of these vegetable acids are tartaric and citric acids.

Inorganic Foodstuffs

The salts taken in as food which are of importance to the organism are sodium chloride, potassium chloride, the phosphates of calcium and magnesium, and iron compounds. Sulphates are of minor importance. The carbonates of sodium (Na_2CO_3 and $NaHCO_3$) are of great importance in the organism: they are, however, chiefly derived from the vegetable acids taken with the food (see p. 400.)

The Change of Foodstuffs in the Body—their Nutritive Functions

Nitrogenous foodstuffs are necessary to animal life: they are the only form in which nitrogen can be assimilated by the organism so as to act as nutriment to the tissues. When taken into the digestive tract, both animal and vegetable proteids (Classes 1–3) become transformed by the pepsin-hydrochloric acid of the gastric juice into syntonin, albumoses, and peptones; by the trypsin of the pancreatic juice into peptones and an intermediate body, while part of the peptone is further split up into two nitrogenous bodies, leucin and tyrosin. These crystalline bodies cannot replace proteids in a diet. They are amido-acids, and like other bodies of their class, except asparagin, they cause a decomposition of proteid in the body if they are given in the food as part of the proteid.[1]

Gelatine is also transformed into albumoses in the stomach and small intestine; keratin is not digested in the stomach but only by the pancreatic juice in the small intestine. The digested products of these bodies differ in chemical reactions from those of Classes 1–3. The difference of nutritive value is greater than that of their chemical reactions.

Some of the native proteids taken in as food may be absorbed as such (Brücke), but most physiologists are agreed that proteids are absorbed from

[1] See P. Bahlmann, Inaug. Dissert. Münster, 1885. Quoted by König, *Nahrungsmittellehre*, Bd. i. p. 121, 3rd edit.

the digestive tract in the form of albumoses and peptones, and, according to the researches of Hofmeister,[1] von Ott,[2] Popoff,[3] and Brinck, they are transformed by the mucous membrane of the stomach and intestine into serum-albumin. Albumoses and peptones thus form an important constituent of the artificial foods for invalids; they do not, however, possess the same nutritive value as the ordinary proteids of food. The well-known experiments of Plòsz and Maly tend to show that they are equal in nutritive value to albumin and other proteids: they fed a dog, for example, on peptone, fat, and carbohydrate for a period of eighteen days, and found that at the end of that time it had gained considerably in weight. According to Voit, however, rats in whose diet peptones are substituted for the ordinary proteids of food succumb after a period of seven months. It is possible that when a large quantity of peptone is given, much of it is split up by the pancreatic juice into leucin and tyrosin, and is thus lost as food to the organism.

We may take the fact as certain that the nitrogenous foods absorbed from the digestive tract become, sooner or later, transformed into one of the proteids of blood; they can in this form be utilised by the tissues. We know also that the end-products of the changes they undergo in the body are nitrogenous excretive matters, urea and uric acid. Some considerations in relation to the metabolism of proteids in the body are, therefore, of extreme importance from a dietetic point of view: these will now be reviewed. The cells which compose the animal body are formed of 'protoplasm,' whether metamorphosed into the nerve-cell, the muscle-fibre, or the chief structures of other tissues. From one point of view protoplasm may be considered as 'living' proteid, since after its death the greater part of it consists of the proteids or nitrogenous substances which are taken in as food. Two considerations are of importance with regard to the life of the cellular elements of the body. (1) In order that they may continue to exist, they must be supplied with nitrogenous food in the form of proteids. (2) By their means the physiological processes of the animal body are carried on. When the body is deprived of nitrogenous food, the tissues do not at once cease their activity, for they have a store of nitrogenous food on which they can draw. This store exists partly in the blood, the so-called 'circulating proteid,' and partly in the tissues themselves: when this is exhausted, the tissues then begin to waste from the insufficiency of nitrogenous food.

Practically speaking, the nutrition of the nitrogenous tissues means the nutrition of the body. Thus the physiological activity of glands, of muscles, of the nerve-cells, of the connective-tissues, of the spermatozoa, and of the ovum depends on the food supplied to and assimilated by them. As regards glands, their secretion is, in the case of the digestive glands, rich in proteid substances which are closely associated with the active agents of the secretion, the ferments. In the connective tissue, also, the fat is stored up by means of the cells it contains; it is not simply located in the tissues; its storing up is due to the assimilating activity of the cell, developed in one particular direction, viz. that of taking in fat. The liver-cells, moreover, take up most of the carbohydrates digested in the intestine, and this assimilation is due to the activity of the living nitrogenous cell. Therefore all the physiological processes of the body occur by means of its nitrogenous cell-elements, and the food we eat to nourish the tissues of the body must be taken up by the

[1] *Arch. f. exper. Path.* Bde. xix. and xx. 1885.
[2] Dubois-Reymond's *Archiv.* 1883.
[3] *Zeits. f. Biologie.* 1889.

cell-elements before it produces its effect. The process of oxidation is also closely associated with the activity of the cell-elements of the tissue, so that, as Pettenkofer and Voit have shown, 'the nitrogenous substances composing the textures of the body *determine* the absorption of oxygen,' and it is not that the 'absorption of oxygen determines the changes in the tissues;' oxidation in the body, moreover, is not proportional to the amount of oxygen inspired, as Lavoisier and Liebig thought, but to the necessity of the tissues for oxygen.

The proper and regulated supply of nitrogenous food to the organism is, as is evident from what has just been said, of prime importance. But in the matter of food, it is difficult, if not impossible, to point out that one foodstuff is more important than another, difficult where a deficiency of any particular foodstuff is detrimental to healthy existence. Nitrogenous food, for example, is essential to life, but so are salts and water, and so, again, are fats and carbohydrates. And although the *rôle* played by the individual foodstuff may be pointed out, the effect of the mixture of foodstuffs is the chief physiological factor in considering food. The results of feeding experiments (in animals) have shown that the proteids taken as food are, to some extent, the source of the fat of the body and of the glycogen found in the liver and muscles; so that, besides being essential to the life of the nitrogenous tissues, they have a nutritive relation to the other two classes of organic foodstuffs, fats and carbohydrates. The relation of proteids to inorganic foodstuffs will be discussed under the head of the latter.

Proteid-sparing Foods

From what has been said, it is evident that an excess of proteid food would throw an excess of work on the nitrogenous tissues. Thus it is found that the decomposition of proteid in the body varies with the amount taken as food; the excretion of urea is greatest with animal diet and less with a diet of vegetable food poor in proteid.[1] To preserve health, the proteid taken must equal that destroyed. No constant figure can be given, however, of the amount of proteid taken as food, for with every individual there is a maximum and a minimum of intake. It is evidently of advantage to the organism if the amount of proteid taken in as food can be diminished by admixture with other foodstuffs, without, at the same time, affecting the organism injuriously, because the diminution of proteid food takes work off the tissues and the digestive organs. Such foodstuffs which in a diet allow the proteid food to be diminished in quantity are called *proteid-sparing foods.* The chief of these are *gelatine*, *fats*, and *carbohydrates.* Gelatine has not the same nutritive value as myosin of flesh, &c.; it cannot completely replace such proteids in a diet. But it has a certain value, for on a diet containing two parts of ordinary proteid to one of gelatine, an animal can maintain health; a fact of both physiological and practical importance. In a dog, for example, as Voit has shown, N-equilibrium is established on a diet in which the nitrogenous food consisted of 400 grammes proteid and 200 grammes gelatine. Gelatine is easily digested in the stomach, but is rapidly oxidised in the body into urea, the excess of which in the system causes diuresis. Chondrin and keratin are far behind gelatine in nutritive value; and as they form only a fractional proportion of food they possess no great practical value. Weiske and others have shown that asparagin (amido-succinamic acid) is a proteid-sparing body in herbivora; in carnivora this action is not certain.[2]

[1] See Lehmann, *Journ. f. prakt. Chemie*, Bd. ii. 1850, p. 447.

[2] Cf. König, *op. cit.* p. 119.

Large quantities of animal food (meat) may be taken: Ranke took as much as 2000 grammes ($4\frac{1}{2}$ lb.), and Rubner, 1400 grammes (3 lb.), in a day. This is of no advantage; it throws great work on the tissues, and, moreover, such a diet cannot be maintained for any length of time. Experiments are not wanting, both in animals and in man, to show that the addition of fat to a diet of proteid is of advantage. In a dog, for example, which has a diet of 1200 grammes of flesh daily, more proteid will be destroyed in the body than is taken as food, while an equilibrium between intake and destruction of proteid is obtained if the diet consist of 500 to 600 grammes of meat and 200 grammes of fat (Rubner). The addition of fat has here acted as a proteid-sparing food. Carbohydrates act in a similar manner.

No definite proof is forthcoming, whether such substances as coca (cocaine) and Kola nut (caffeine), &c., are proteid-sparing materials: such experiments as have been performed tend to show that these substances may diminish the intake of food, but are eventually detrimental to the organism, owing to the effect of their active principles on the central nervous system. They may, however, have some use in hard work, such as in forced marches and efforts of endurance.

Fats.—The use of fats in the organism is that they are sources of energy and of heat to the body. In the majority of diets of the nations of the world fat finds a place, and in some cases (that of the Esquimaux) it is greatly increased in the dietary. In hard work, too, an excess of fat is taken. Whatever the mixture of fats taken in as food, the body-fat always has the same composition: this fact agrees with the conclusion that the deposition and metabolism of fat in the body is due to cell-activity, and that the fat in part comes from the proteid and from the carbohydrate food.

Carbohydrates not only act as proteid-sparing foods, but they are also *fat-sparing*. They diminish the consumption of fat by being a source of energy in the body, and thus when present in a diet in which but little fat is present, they diminish the oxidation of fat in the body. They are also a source of fat, as has been abundantly proved by the experiments of Lawes and Gilbert, and others. Carbohydrates, however, differ from fats in that the amount ingested is proportional to the quantity of carbonic acid (CO_2) excreted: there is no such relation with fats. For oxidation, carbohydrates require only sufficient oxygen to unite with their carbon, since the hydrogen and oxygen are in the proportion to form water; but fats require oxygen to oxidise their hydrogen as well as their carbon. The question whether fats and carbohydrates can replace each other completely in a dietary is not as yet definitely answered. Practically, however, it is in part settled by a consideration of the diets used by civilised nations: in all of these, both fats and carbohydrates find a place. The first question, therefore, as to whether it is possible to maintain health on a diet of proteids, fats, salts, and water, and on one of proteids, carbohydrates, salts, and water, is one of greater physiological than of practical import. It is, however, an important point to discover in what proportion fats and carbohydrates are mutually interchangeable in a dietary. Carbohydrates are cheaper than fats, and thus form a large part of the diet of the poor; and this is a practical aspect of the question. Life and a certain degree of health can be maintained on a diet of proteids, fats, salts, and water, and fat seems essential in the dietary of man. If an excess of fat, however, be present in the diet, it is not digested, but passes away with the fæces and favours decomposition in the digestive organs, which are thus put out of order. An excess of carbohydrates, on the other hand, owing to the large bulk of food taken, also deranges the digestion (see under Digestibility of Food, p. 419). The conclusion, therefore, seems

to be in favour of an admixture of fats and carbohydrates in the diet. As, however, these foodstuffs perform similar functions in the body, they can be expressed in dietetic terms of each other (see NUTRITIVE VALUE OF FOODSTUFFS, p. 401).

Inorganic Constituents of Food

These play an important part in the dietary. Without them, indeed, life is no longer possible.

Water is necessary for the proper carrying on of all the chemical and mechanical functions of the body, for producing a medium for the solution of the digestive juices, for aiding the absorption of the products of digestion, for the excretion of substances from the body, and for the dispersion of heat from the lungs and skin. The water in the body is chiefly derived from that taken in as food, but a portion is obtained by the oxidation of the hydrogen in tissues, about 296 grammes daily. A want of water tends rapidly to death.

Sodium chloride ($NaCl$) is essential to life; its complete withdrawal from the food leads to dissolution. Since it exists in very small proportion in vegetable foods, it is a necessity to vegetable feeders. In the making of bread, for example, the sodium chloride added supplies the deficiency of sodium and chloride which exists in flour. With animal feeders the use of common salt is not so peremptory, since the fluid which bathes muscular tissue like other animal fluids contains a sufficient quantity. The uses of chlorides in the organism are very important; they keep in solution the globulins of the blood and other fluids; they are closely associated with the proteids of the tissues, although the utility of this association is at present unknown; they are the source of the hydrochloric acid of the gastric juice, so that a deficiency of chlorides in the food leads to digestive disturbances, the hydrochloric acid in the stomach diminishing while the sodium chloride of the blood is not affected to any great extent.[1] Albuminuria is a secondary result of 'chlorine-hunger.'

Phosphates are also essential to life, especially to the growing organism; and where development is taking place, there are always present phosphates, sulphur, and calcium. Young animals, as Kemmerich has shown, when fed with food poor in potassium phosphate, soon die, the muscles being chiefly affected.[2] In the body, phosphates are united with alkalies, *sodium*, *potassium*, *calcium*, and *magnesium*.

The sodium salts are in the form of normal sodium phosphate (Na_3PO_4) and di-sodium phosphate (Na_2HPO_4), while the potassium is salt in the form of di-potassium phosphate only (K_2HPO_4). Phosphates, like chlorides, are peculiarly associated with proteids, although the utility of this association is not understood. The phosphates of calcium and magnesium have special functions to perform, since they constitute the chief solid parts of bone. They are of great importance, therefore, to the growing organism. When the food is deficient in calcium, and to a less extent of magnesium, the bones of growing animals are badly developed, and may become rickety.[3] There is apparently some relation between the ingestion of calcium salts and of sodium chloride, for the former may be abundant in the food, and yet be for the most part excreted in the fæces combined with fatty acids. This non-absorption of calcium, so important a body to the child, may be due, as

[1] Förster, *Zeits. f. Biologie*, Bd. ix. 1873, p. 342.

[2] Pflüger's *Archiv*, Bd. ii. 1869, p. 85.

[3] Roloff, *Arch. f. wissenschaftl. u. prakt. Thierheilk.* Bd. v. p. 152; Dusart, *De l'Inanition minérale.* Paris, 1874.

Förster has pointed out, to the diminution of the hydrochloric acid in the gastric juice, owing to a deficiency of chlorides in the food: it is through the acid gastric juice that calcium salts are absorbed.

The *carbonates* present in the body are derived from two sources: a small quantity is taken in with the food, but the greater part is derived from the vegetable acids of the food—acetic, tartaric, citric, malic, and lactic—which are changed into carbonates in the system. Some of these acids (lactic, for example) are probably derived in part from the splitting up of carbohydrates in the body; so that in this indirect way carbohydrates may aid in maintaining the alkalinity of the blood and animal fluids—both the interstitial fluids of the tissues and the alkaline secretions, such as that of the salivary glands and of the pancreas. Besides this important function, carbonates in the form of carbonate of calcium form an integral part of bony tissue.

Sulphates exist in only small quantity in the body: they are not of such importance as the salts already considered, although organic sulphur (such as exists in proteids) is essential to growth. A small quantity of sulphates is taken in with the food and a little is formed in the body by the oxidation of albuminous substances containing sulphur.

Iron is essential to health and to life: it forms an important part of the hæmoglobin of the red corpuscles. It is contained in many foods, especially animal.

Nutritive Value of Foodstuffs

In the preceding section a short account has been given of the part played by the different foodstuffs in the body. It is now necessary to discuss their *nutritive value.* It is evident that the nutritive value of the salts and water of food is easily determined, since they do not undergo the great chemical change that proteids, fats, and carbohydrates do in the organism. Their nutritive value, therefore, may be expressed in terms of the quantity ingested, with the requisite proportion of the different saline constituents. But with proteids, fats, and carbohydrates the case is different: the changes they undergo in the body are complicated, and the functions they perform are numerous, and at present incompletely understood, so that it is impossible to so express their nutritive value accurately. An approximate estimate, however, is not without its importance. All the processes of the body are attended with the manifestations of energy, this being in two forms, mechanical labour and heat. The process going on in all the cells of the body are thus manifestations of energy. The contraction of muscles, the beat of the heart, and the metabolism of cells develop energy in their occurrence. With regard to mechanical labour, the amount of energy expended by the body may be calculated; a good day's work, for example, would be equal to about 150,000 metre-kilogrammes.[1] With heat, however, it is different. The amount formed in the body has not yet been accurately measured, in spite of numerous experiments. A useful proportion to recollect, however, between the amount of mechanical labour and heat expended by an adult in a fair day's work is one-sixth or one-fifth mechanical labour to five-sixths or four-fifths heat. Food is the means by which this loss of energy to the body is made good. The foodstuffs possess a certain amount of potential energy which may be expressed either in terms of heat or of

[1] The amount of energy required to raise 1 kilogramme 1 metre high is taken as the unit of force: on the English scale, the unit is a foot-pound.

The amount of heat required to raise 1 gramme of water 1 degree Centigrade is the unit of heat, or 1 calorie.

mechanical labour. This potential energy is different in each particular kind of foodstuffs, not only in the classes of proteids, fats, and carbohydrates, but also in the individual members of each of these classes. The potential energy of any foodstuff is calculated by estimating the amount of heat used on the complete combustion of a certain weight of the substance; and this heat can be expressed in foot-pounds or metre-kilogrammes by calculating how much work the heat can do.

By this means the following calculations have been made:—

Substance—one gramme (dried)	Give rise to gr.-degrees[1]	Metre-kilogrammes
Casein	5,855	2,488
Peptone	4,876	2,072
Ox-flesh	5,724 (5,103)[2]	2,432 (2,161)[2]
Gelatine	5,493	2,334
Gluten	6,141	2,610
Legumin	5,573	2,368
Ox-fat	9,686 (9,069)[2]	4,116 (3,841)[2]
Palmitin	8,883	3,775
Stearin	9,036	3,840
Olein	8,958	3,807
Butter	7,264 [2]	3,077 [2]
Starch	4,479	1,903
Arrowroot	3,912 [2]	1,657 [2]
Dextrose	3,939	1,674
Maltose	4,163	1,769
Cow's milk	5,733	2,436
Human milk	4,837	2,055
Potatoes	4,234	1,799
Wheaten bread	4,351	1,849
Rice	4,806	2,042
Peas	4,889	2,077
Alcohol	6,980	2,966
Liebig's extract of muscle	4,400	1,870
Urea	2,537 (2,206)[2]	1,078 (934)[2]

These are figures for the complete oxidation of the foodstuffs, but in the body it is only the fats and carbohydrates which are completely oxidised; the proteids get no farther than the stage of urea. In expressing, therefore, the available potential energy of food proteids, the potential energy of urea (2,537 calories) must be subtracted. One gramme of dry proteid gives rise to about $\frac{1}{3}$ gramme urea; therefore, according to Frankland's figures, the available potential energy of one gramme of proteid is as follows:—

	Gr.-deg.	Met.-kilo.
1 gramme of dried ox-flesh	5,103	2,161
minus		
$\frac{1}{3}$ gramme urea	735	311
Available potential energy of proteid	4,368	1,850

Danilewsky gives the available energy of one gramme of albumen as 5,100 calories (5,945 *minus* one-third of 2,537).

From what has been said, it is evident that foodstuffs may be expressed in equivalents in terms of energy; to foods which when burnt yield the same number of calories the term *isodynamic* has been applied. From the point of view of energy we may say, therefore, that so much proteid is isodynamic with so much fat or carbohydrate. Rubner has calculated that 100 grammes

[1] One gramme-degree, or calorie, is equivalent to 0·425 kilogramme-metre; or, better expressed, one kilogramme-degree is equivalent to 425 kilogramme-metres.

[2] Frankland, *Phil. Mag.* xxxii. p. 182. The other figures are from Danilewsky. F. Stohmann and others give somewhat different figures. See *Journ. f. praktische Chemie*, N.F. Bd. xxxi. p. 273; Bd. xxxii. pp. 93, 407, 420.

of animal albumin = 52 grammes of fat = 114 grammes of starch = 129 grammes of dextrose. Also that 100 parts of fat are isodynamic with 232 parts of starch, 234 parts of cane-sugar, and 256 parts of dry dextrose, making a mean of 250 parts of carbohydrate.[1]

From a dietetic point of view, however, it is not so much a question of the energy developed by the burning of the foodstuffs outside the body, but of the amount of their potential energy which is available during combustion in the organism. Theoretically, the potential energy ought to be equal to the energy developed by them in the body; and this was Liebig's notion when he stated that 100 grammes were equivalent to 240 grammes of carbohydrates (Rubner says 250 grammes). But owing to the varying digestibility and absorption of foodstuffs, and probably to many metabolic conditions in the body with which we are at present imperfectly acquainted, only a portion of the potential energy of foodstuffs is actually available to the organism. Rubner has stated that in man the available heat units for 1 gramme of albumin are 4,100; 1 gramme of fat, 9,300; and 1 gramme of carbohydrate, 4,100. These figures differ considerably from the total potential energy of the foodstuffs. By another method, Pettenkofer and Voit have come to the conclusion that 100 grammes of fat is equivalent to 170 or 180 grammes of carbohydrate *in a dietary*; a conclusion which may be taken as more correct than deductions from mere calculations of potential energy.

This question of potential energy of foodstuffs is therefore merely an indication of their nutritive value in a particular direction. To say, for example, that so much fat is isodynamic in the body with so much carbohydrate does not mean that it is of no consequence to the health of the organism whether the non-nitrogenous foodstuffs of the diet be given in the form of fat *or* of carbohydrate. As we have seen, not only physiological considerations, but the custom of communities, have decided that health is best maintained when carbohydrates *and* fats form part of the diet.

Other points must be considered in dealing with the nutritive value of foods and foodstuffs: the chief of these are their digestibility, associated closely with the changes produced by cooking and the preparation of food and with the bulk of food taken; the interaction of the foodstuffs and the effect of adventitious substances in food; the effect on food of food-accessories. These subjects will be discussed afterwards.

Another question arises in considering the nutritive value of foods, and that is whether individual members of the classes of proteids, fats, and carbohydrates do not differ from each other in nutritive value. There is not much known on this point. We have seen that among proteids, the members of the sub-class of albuminoids (gelatine, &c.), have not the same nutritive value as ordinary proteids; but it is usually considered that the animal proteids (myosin, egg-albumin, &c.) have the same nutritive value as the vegetable proteids (gluten, legumin, &c.) This has been confirmed by the carefully conducted experiments of Dr. Rutgers on himself.[2] There are, however, undoubtedly individual differences in nutritive value in proteids, which further research will perhaps elucidate; but these differences are perhaps not great, and it may be concluded that man has chosen the three best proteids for his food in the myosin of meat, the casein of milk, and the gluten of bread.

The differences in nutritive value of fats seem to depend almost solely on their digestibility (see p. 420).

[1] *Zeits. f. Biol.* 1883, p. 312. Quoted by König.
[2] *Zeits. für Biol.* Bd. xxiv. 1887, p. 351.

The differences in carbohydrate foods cannot at present be correctly estimated. There is very little evidence to show that starch, dextrose, maltose, and cane-sugar differ in nutritive value. Lawes and Gilbert, however, consider that cane-sugar is rather more fattening than starch.[1]

The question as to the most advantageous form in which to take proteids, fats, and carbohydrates is not simply one of the nutritive value of mixed foods—such as meat, bread, potatoes, &c.—it is a question of digestibility, bulk of food, &c.; so that the discussion of this point is best taken under the consideration of diet.

Diet and Dietaries

To preserve health, a diet containing proteids, fats, and carbohydrates, with salts and water, is necessary. It has been pointed out that proteids, salts, and water are essential to life; and it has been shortly discussed to what extent fats and carbohydrates are mutually interchangeable in a dietary. Whatever may be the physiological import of the interchangeability of fats and carbohydrates, the question is practically settled by the consideration that both in the diets of nations and in the standard diets calculated from laborious research it has been found advantageous to include both fats and carbohydrates. For practical purposes, therefore (and diet is essentially a practical question), we cannot consider the two classes of non-nitrogenous organic foodstuffs as completely interchangeable, notwithstanding, as has been previously pointed out, the fact that their physiological *rôles* are very similar.

Under the heading Diet we have to consider the *quantity* of foodstuffs requisite to preserve health. This quantity is, however, not fixed; each individual differs in the amount of food required to support health, and in each individual there is a minimum and maximum of the daily ingesta, beyond the bounds of which health is not maintained. Diet is also affected by several conditions. To some extent *sex* influences it: *age* greatly affects the daily ingestion of food; the dietary of childhood (the period of growth), that of adult life (the period of vigour), and that of old age (the period of decay or of inactivity) differing in important particulars. *Work* has great influence on diet; *climate* and the *temperature* of the air have only a slight effect.

The *standard diets* which have been compiled from the results of experiments vary to some extent in the quantity of foodstuffs contained in them, so that they can only be considered as approximate. The methods by which they have been obtained may be briefly stated. A healthy individual is selected, and the exact quantity of foodstuffs is estimated by experiment, requisite to preserve an equilibrium between the amount of carbon and nitrogen taken into the body and that discharged from it. This method has, however, to be corrected by two other methods—1, estimating the amount of foodstuffs present in the daily food used by communities of men, that used in families, by labourers of a class, and in ships; 2, by weighing the amount of daily food uniformly used by a single healthy individual, and then estimating the quantity of combustible foodstuffs.

By experiments of this kind, the diets of *subsistence*, during *rest* and during *work*, have been calculated. The diet of subsistence is of physiological interest only, because it is calculated only in proportion to the internal needs of the organism. But such absolute rest is not possible in health; so that on a subsistence diet a man would waste. The diet of rest implies very little exercise: that of work varies with the amount of work done.

In the following tables the foodstuffs are reckoned in grammes as water-free, the daily amount of water requisite being placed under a separate

[1] *Brit. Assoc. Report*, 1854.

heading, and the calculation is for a man of average weight, 68 kilogrammes, or 150 pounds.

—	Subsistence diet (Smith and Playfair)[1]		Average diet of rest (weight of man, 60–70 kg.)	
	Grammes	Oz. avoir.	Grammes	Oz. avoir.
Proteid	66	2·32	100	3·52
Fat	24	0·84	50	1·76
Carbohydrate	330	11·5	400	14·08
Salts	14	0·5	—	—
Total	434	15·16	—	—

The diet of rest, however, varies like other diets. Thus Pettenkofer and Voit[2] found that in a strong workman, during rest, the diet contains 137 grammes of proteid, 72 of fat, and 352 of carbohydrate. He gave, moreover, to a resting soldier a diet containing 86·3 grammes of proteid, 108·9 grammes of fat, and 331·4 grammes of carbohydrate, and found that he lost 10 grammes of proteid daily from the body.

Diet for a Man weighing 150 *lb. during Work*

—	Medium work				Severe work				Very laborious work	
	Moleschott		Pettenkofer and Voit		Ranke		Moleschott		Smith & Playfair (average)	
	Gr.	Oz. av.	Gr.	Oz. av.	Gr.	Oz. av.	Gr.	Oz. av.	Gr.	Oz. av.
Proteid	130	4·59	137	4·83	100	3·52	140	4·94	184	6·50
Fat	84	2·96	117	4·12	100	3·52	90	3·17	71	2·85
Carbohydrate	404	14·26	352	12·40	240	8·46	434	15·31	570	20·10
Salts	30	1·06	30	1·06	25	0·89	32	1·13	40	1·40
Total dry food	648	22·87	636	22·41	465	16·39	696	24·55	865	30·85

Of these diets, that of Moleschott's for medium work has been taken as the average diet for the adult man. Ranke's diet, which is superior in that it contains more fat, was calculated from experiments on an individual whose body-weight was 74 kilogrammes (163 pounds).

Relation of Total Water-free Food in Daily Diet to Body-weight

—	Subsistence diet	Medium work		Very laborious work
		Moleschott	Ranke	Grammes
Proportion per kilo. of body-weight	6·4	9·5	6·3	12·7
Proportion of total body-weight	$\frac{1}{156}$	$\frac{1}{105}$	$\frac{1}{157}$	$\frac{1}{78}$

From this table it will be seen that Ranke's diet for medium work is actually less than Playfair's subsistence diet, and differs greatly from Moleschott's. Ranke's results may be taken as true for the particular individual experimented upon, but Moleschott's is a better average diet.

Amount of Carbon and Nitrogen in Diets.—The carbon and nitrogen of the foodstuffs are the chief elements which undergo metabolism in the body; and from one point of view the food ingested may be looked upon as so much carbon, nitrogen, hydrogen, and salts.

[1] See E. Smith, *Ann. Report to Privy Council*, 1863 and 1864; also Playfair, *Edinburgh Med. Philosophical Journal*, 1854.

[2] *Zeits. f. Biol.* Bd. ii. 1866, p. 488.

The following table shows the quantity of carbon, nitrogen, &c., in 100 grammes of each dried foodstuff:

100 grammes of dried foodstuff contain of	Carbon	Nitrogen	Hydrogen	Sulphur
Proteid (average)	53·0	16·1	7·1	1·15
Fat	76·5	—	10·9	—
Carbohydrates:				
Starch	44·4	—	—	—
Cane-sugar	42·1	—	—	—
Lactose	42·1	—	—	—
Glucose	40·0	—	—	—

Converting Moleschott's diet into terms of carbon, nitrogen, &c., we obtain the following figures:—

Nitrogen	20·9	grammes or	321	grains
Carbon	307·0	„	4,737	„
Hydrogen	11·6	„	179	„
Sulphur	1·8	„	28	„
Salts	30·0	„	464	„

Roughly speaking, therefore, the average diet ought to contain in the form of foodstuffs 20 grammes of nitrogen and 300 grammes of carbon.

Salts and Water of the Diet.—The loss of water from the lungs and skin, and in the urine and fæces, is continuous, but varies during rest, during work, and with changes of external temperature. Pettenkofer and Voit [1] give the following figures for rest and work:—

Daily Loss of Water from Body in Grammes

—	During rest	During work
	Grammes	Grammes
By urine	1,200	1,150
By fæces	110	80
By skin and lungs	930	1,730
Total	2,240	2,960

Part of the water lost is replaced by the combustion of hydrogen in the body: this is equal to 296 grammes daily; the remainder is made up by the water taken in with the food, which varies from 2,700 to 2,800 grammes daily (70 to 80 ounces).

The total amount of *salts* needed daily has been already given, viz. 30 grammes. These salts consist of chlorides and phosphates united with sodium, potassium, calcium, and magnesium. Iron is taken in the food united with complex organic compounds.

The chief salts taken in as food are sodium chloride, potassium, calcium, and magnesium phosphates; the first chiefly from animal foods or added to the food, the latter chiefly from vegetable food; milk, however, contains a sufficient proportion, not only of sodium chloride, but of potassium and calcium phosphates and iron. Owing to the deficiency of sodium chloride in vegetable food, it is a necessity which is added to the food of those who feed chiefly on carbohydrates and plant proteids; the animal feeder, on the other hand, gets a sufficiency of sodium chloride in his food; and when added to animal food, sodium chloride is more of a condiment than a food. More sodium chloride is necessary to vegetable feeders, because in man

[1] *Zeits. f. Biol.* Bd. ii. 1866, p. 459.

potassium salts increase the excretion of sodium chloride in the urine. In vegetable food there is twice or three times the amount of potassium salts that exists in animal food (see sections on separate foodstuffs).

Influence of Constitution and Work on Diet.—It has been stated that there are great individual differences in the diets, due chiefly to the different physiological conditions of men and to the different surrounding conditions. The chief difference between the diets of men, however, is due to the amount of mechanical labour they perform. The greater the work done, the larger the amount of food necessary, and in the diet (see table) the proteids and fats are chiefly increased. Although work does not increase the excretion of nitrogen, as has been shown by the experiments of Fick and Wislicenus and others, yet by work the living nitrogenous muscle is made physiologically active: this leads to partially using up the muscle substance, which has to be replaced by the taking in of nitrogenous food. Moreover, the increase of proteids in the diet is necessary for the hypertrophy of the muscles which occurs during prolonged efforts.

The influence of *sex* on diet rests chiefly on the greater manual work that men do; the woman's diet being $\frac{3}{4}$ to $\frac{4}{5}$ that of the man's. An increased amount of food is taken by the woman during lactation, and probably during gestation also.

Climate influences diet to some extent. Thus in cold countries the fat of the diet is increased. Great stress has been laid on the fact that some of the nationalities in India subsist chiefly on carbohydrate food and do great work on it. Carbohydrates, however, do not form a large part of the diet if animal food can be procured; so that its extensive use is due more to economical necessities than to its being advantageous.

Influence of Age.—Diet varies in childhood and in old age from that which we have discussed as essential to health in adult life. During childhood, from birth to puberty, the organism is growing, tissues are developing, especially the nervous, muscular, and bony tissues; food has to be supplied for the growth of these tissues, as well as to maintain the nitrogen-equilibrium of the body. In old age less food is required than in adult life, owing to the diminished metabolism of the body and the cessation of mechanical labour. In old age there is diminished excretion of carbonic acid.

Childhood.—During the first six months of life, the child grows rapidly. According to Vierordt, during this time it gains from 120 to 300 grammes (4·5 to 10·5 ounces) per week; during the second six months the gain is less, being 100 to 200 grammes weekly; while during the second year it is 50 to 100 grammes a week.[1] The rapidity of gain of weight then diminishes up to puberty.

The following table[2] shows the *minimum* daily need of foodstuffs at different ages:—

Condition	Weight in grammes		
	Proteid	Fat	Carbohydrates
Child up to $1\frac{1}{2}$ year (average)	20–36	30–45	60–90
„ from 6–15 years (average)	70–80	37–50	250–400
Man (moderate work)	118	56	500
Woman (moderate work)	92	44	400
Old man	100	68	350
Old woman	80	50	260

[1] *Physiologie des Kindesalters.* Tübingen, 1877.

[2] König, *Procent.-Zusammensetzung der menschl. Nahrungs-Mittel,* &c. Berlin, 1888.

The carbohydrate and fat in the diet of the child is proportional to the carbonic acid excreted. Of mineral foods, besides sodium chloride calcium and magnesium salts and phosphates are most essential to the child. About 5 per cent. of the food is undigested in children.

The diet of children varies with rapidity of growth, and also in different individuals. The daily minimum necessary for growing children is as follows :—

Of proteid . .	2·3 to 3·0	grammes per kilogramme of body-weight;
Of fat . .	2·1 to 2·6	,, ,, ,,
Of carbohydrate	9·5 to 12·3	,, ,, ,,

Meat, milk (milk products), bread, and flour make up the diet of children, peas, potatoes, and other vegetables being adjuncts only. One litre of milk (35 ounces) contains half the proteids required by the child daily—i.e. about 38 grammes (see p. 429). Up to the fourth year of age milk forms practically half the diet of the child; from that age to the eleventh year it forms about one-third (Camerer). From the fourth year, also, the vegetable food is increased in the diet.

A complete daily diet for children of six to seventeen years is as follows:[1]

Article of food	Weight in		Proteids	Fat	Carbohydrates
	Grammes	Oz. avoir.	Grammes	Grammes	Grammes
Meat (raw)	170	6·0	30·0	17·0	—
Bread	300	10·5	19·5	1·0	150
Potatoes	180	6·3	3·0	0·3	36
Fat (butter and lard) .	15	0·5	—	14·0	—
Milk	250	8·8	8·5	9·0	12
Flour (for soup) . .	100	3·5	10·0	1·0	74
Vegetables (various) . .	180	6·3	7·0	1·0	9
Total . .	1,195	41·9	78·0	43·3	281

To such a diet must be added food-accessories, such as coffee, tea, chocolate, and flavouring materials.

The diet of *old age*, which is given on p. 407, is important for consideration in public institutions, almshouses, &c., where the aged poor are cared for. The figures given above represent the *minimum* diet; but in many institutions less food is taken. Thus Förster found in an almshouse that each man received daily 91·5 grammes of proteid, 45·2 grammes of fat, and 331·6 grammes of carbohydrates, part of the food consisting of 171 grammes of meat (without bone) and 282 grammes of bread; each woman received 79·1 grammes of proteids, 48·6 grammes of fat, and 265·1 grammes of carbohydrates, partly contained in 94 grammes of meat (without bone) and 259 grammes of bread, with cheese.

The Proportion of Nitrogenous to Non-nitrogenous Foodstuffs in a Diet.—The amount of proteid daily necessary for the organism is a more or less constant quantity; as we have seen, a certain minimum must be ingested to feed the nitrogenous tissues, to maintain the N-equilibrium, and to carry out the other functions of proteid food which have been already indicated. As we have seen, also, the functions performed by the non-nitrogenous organic foodstuffs—fats and carbohydrates—in the organism are more or less similar, though there are reasons why *both* forms should be included in a diet. We have now to consider the proportion between the nitrogenous and non-nitrogenous foodstuffs in different diets, and also between fats and carbo-

[1] König, *Zusammensetzung der menschl. Nahrungs-Mittel*, Bd. i. 1889, p. 149.

hydrates; in other words, with regard to the latter question, what proportion between fats and carbohydrates is the most advantageous in a diet.

From numerous experiments, it has been concluded that the proportion between the nitrogenous and non-nitrogenous organic foodstuffs in a diet ought to be as 1 to 3·5 or 4·5; this is the average. Thus, in Moleschott's diet, the proteids (130 grammes) are to the non-nitrogenous (fats, 84 grammes + carbohydrates 404) as 130 : 488, or 1 : 3·9. And this relation is preserved, not only in the diets of adults in moderate work, but in the diet of laborious work, in that of childhood, and in that of old age.

Taking Pettenkofer and Voit's conclusion that 100 grammes of fat is isodynamic with 175 grammes of carbohydrate (p. 403), we may express the non-nitrogenous organic foodstuffs of a diet in terms either of fat or of carbohydrate. Thus, taking Moleschott's diet, containing 84 grammes of fat and 404 grammes of carbohydrate daily, the non-nitrogenous foodstuffs would be expressed—

a. In the form of Fat

84 grammes of fat	84
404 grammes of carbohydrate, equal to (175 = 100)	231
	315 grammes

b. In the form of Carbohydrate

84 grammes of fat, equal to (100 = 175)	147
404 grammes of carbohydrate	404
	551 grammes

In one case, therefore, the non-nitrogenous foodstuffs would be taken in the form of 315 grammes fat; in the other of 551 grammes carbohydrate. We shall see reasons why neither of these modes of taking non-nitrogenous food is advantageous. In the following table[1] the proportion of fat to carbohydrates is given for diets under different conditions.

Fat in the diet of	*is as 1 to*	
Child at breast	„	1·4 carbohydrate
Child five months old	„	1·4 „
Workman's child	„	5·6 „
Adult (in easy circumstances)	„	3·4 „
Adult workman	„	5·0 „
Old man	„	5·1 „
Old woman	„	5·3 „
Nursing woman	„	2·4 „.

According to Voit,[2] the proportion of fat to carbohydrates in the daily diet ought not to be less than 1 to 9, which would mean 56 grammes of fat and 500 grammes of carbohydrates. Increase of carbohydrate above this amount is disadvantageous to the organism. We have seen that fat is increased in the diet when laborious work is performed, and in very cold climates, its great potential energy being of service to the organism.[3] Carbohydrates are increased in a diet out of the standard proportion to fat in the food of the poor, because they are cheaper, the chief part of the fat of food being derived from animal food, which is dearer than vegetable. As wages improve, however, the carbohydrates are diminished and more animal food and fat are taken.

For the effects of an excess of fat and of carbohydrates on digestion, see DIGESTIBILITY OF FOOD (p. 420).

[1] Förster, art. 'Ernährung,' Ziemssen's *Handbuch*, p. 137.

[2] Quoted by Förster, *loc. cit.*

[3] Potential energy of one gramme of fat = 9,070 calories (Frankland); of one gramme of grape-sugar, 3,939 calories (Von Reichenberg).

Construction of Diets with Articles of Food

The particular dietary of a race is the result of ancient traditional rules, purely empirical; these rules naturally alter with the varying surrounding conditions and modes of life of the people. It would be out of place here to deal with the various diets of different races; only the diet of civilised peoples will be discussed.

The construction of a dietary and the examination of a given diet are of importance, not so much to the well-to-do, but to soldiers, sailors, and other collections of individuals who are fed *en masse.*

It will be well to recapitulate the several points to which attention must be directed in regard to food:—

1. The necessary daily quantity of foodstuffs has already been discussed. It varies with childhood, adult life, and old age, and with the amount of mechanical labour performed. The last point is important, and it necessitates an increase in the organic constituents of the diet.

2. Even though the daily necessary amount of foodstuffs may be ingested the body may suffer, and this is due to several causes:—

(*a*) Conditions of digestibility; the food being rendered indigestible by being taken in too great bulk, or by containing a large amount of cellulose, or by being too acid, or by being badly cooked.

(*b*) The flavouring may be deficient or of too uniform a character. In large institutions the condition of the inmates is materially improved in some cases by attending to this point.

(*c*) If one food is continued for too long a time, it is finally refused or not eaten with relish.

No mere calculation, therefore, of the amount of foodstuffs can gauge the efficacy of a particular diet. The other conditions just mentioned must be also considered.

Milk has been considered by some as the type of a perfect food. It contains 4 per cent. (by weight) of proteid, in the form chiefly of casein, but also as albumin in very small quantity;[1] 3·7 per cent. of fat (butter); 4·8 per cent. of carbohydrates in the form of lactose; and 0·7 per cent. of salts, with 86·8 per cent. of water. The proportion between the proteids and the non-nitrogenous organic foodstuff is as 1 to 2·125, and the proportion of fat to carbohydrates is as 1 to 1·4. In cow's milk, therefore, the proportion of nitrogenous to non-nitrogenous foodstuffs does not reach the normal, which is 1 to 3·5 or 4·5. Cow's milk is therefore not a perfect food for man. In human milk, however, which contains less proteids than cow's milk, but more carbohydrates, this ratio is as 1 to 4. Human milk is therefore more suited to the child than cow's milk, and the latter is brought up to the standard of human milk by removing some of the casein, by diluting with water and adding carbohydrates, such as sugar (see MILK, p. 428).

The salts of milk consist mainly of sodium chloride, and potassium and calcium phosphates. Calcium phosphate, which is so important to the child, is taken in greater quantity (four to five times) in the day than is stored up. During the lactating period about 5·5 grammes of calcium phosphate is stored up each week, which is equivalent to an increase of weight of one kilogramme in the first year (Förster). Although milk is both scientifically and practically the proper food for children (cow's milk to a less extent than human milk), for adults it is not so suitable, chiefly because the great quantity of water taken with the food is prejudicial to the healthy digestion of adults.

[1] What has been described as 'lacto-protein' and 'other proteids' are probably not normally present in milk: they are due to decomposit on of the casein and albumin.

In adults the diet is mainly composed of meat of varying degrees of fatness, butter, bread, and potatoes; these must be considered as the chief articles of diet, although in some countries rice and maize take the place of bread and potatoes as carbohydrate food.

The annexed diagram, taken from König, shows the proportion of foodstuffs in these articles of diet:—

A glance at the diagram will show that in none of the articles of diet, with the exception of milk, is the proportion between the nitrogenous and non-nitrogenous foodstuffs as 1 to 3·5–4·5. In beef the proportion is about 4 to 1; in eggs, about 1 to 1; in bread, 1 to 8; in potatoes, 1 to 10; in peas, 1 to 2·3. In peas, therefore, the proportion approaches the normal. A single food is, therefore, on these grounds alone, not of the composition requisite to supply the daily need of foodstuffs. If beef, e.g., formed the sole article of diet, an excessive quantity would have to be taken to procure the daily need of non-nitrogenous food. In the same way, if vegetable food (with the exception of peas and beans) formed the chief article of diet, a very large quantity would be necessary to obtain the requisite amount of proteid.

This is shown in the following table, in which, Moleschott's diet being taken as the standard, the

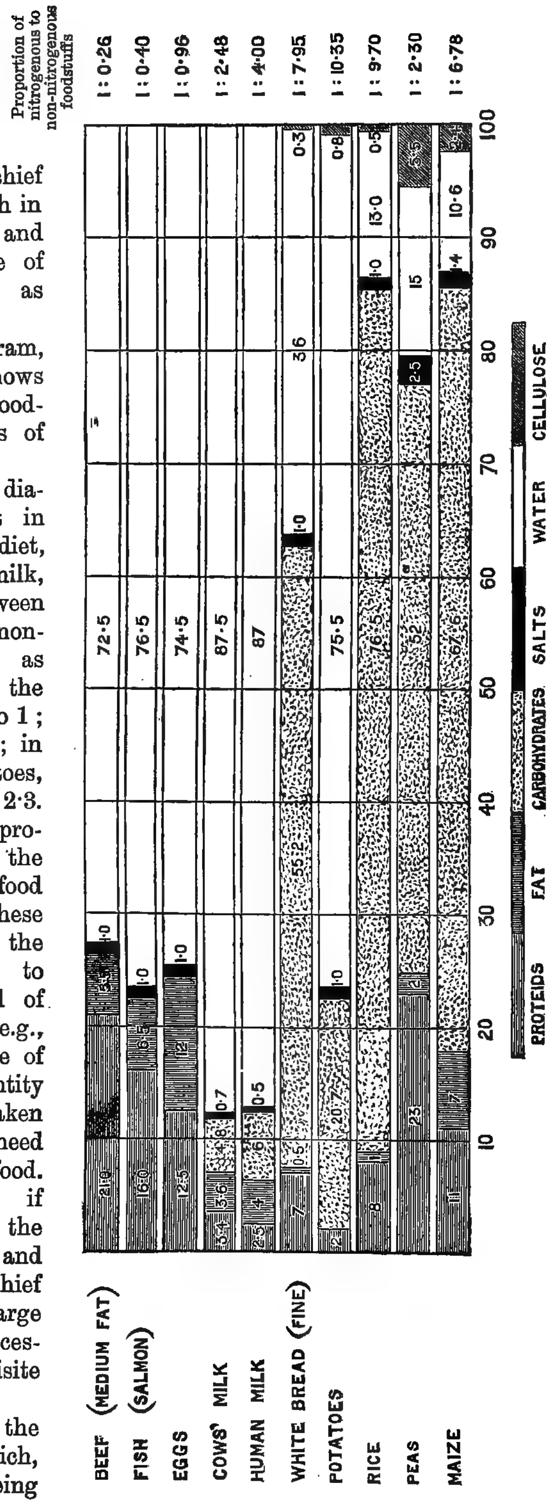


Fig. 86.—Diagram to show percentage composition of various foods (altered from König).

quantities of foods are given containing the daily need of the different food-stuffs:—

Moleschott's Daily Diet: Proteids 130 *grammes* (4·59 *oz.*), *Fats* 84 *grammes* (2·96 *oz.*), *Carbohydrates* 404 *grammes* (14·26 *oz.*)

Food	To obtain					
	130 grammes proteids		84 grammes fat are requisite		404 grammes carbohydrates	
	Gr.	Oz. avoir.	Gr.	Oz. avoir.	Gr.	Oz. avoir.
Of beef	604	21·3	1,527	53·8	—	—
Of eggs	946	33·3	700	24·6	—	—
Of milk	3,250	5pt.14oz.	2,270	4 pts.	—	—
Of cheese	388	13·3	345	12·0	—	—
Of fat of meat	1,487	52·3	112	3·9	—	—
Of butter	—	—	95	3·3	—	—
Of lard	—	—	84	2·96	—	—
Of peas	565	20·0	—	—	777	27·4
Of maize	1,300	45·8	1,254	44·2	626	22·0
Of rice	1,625	57·3	—	—	521	18·3
Of wheaten bread (fine)	1,857	65·5	—	—	732	25·8
Of potatoes	6,500	229·2	—	—	1.951	65·9

The nutritive value of the food articles will be discussed under the heading of each. It is necessary, however, here to point out the most advantageous way in which these food articles can be combined in a diet. For this purpose we may divide articles of food into animal and vegetable, the animal foods supplying the chief part of the proteids and the fat almost exclusively, the vegetable supplying the carbohydrates and a small part of the proteids, while the salts come from both classes of food, some vegetables (the succulent especially) being taken chiefly for the salts they contain.

In translating the elements of a diet into terms of food articles, it is essential to remember (1) the effects on the food of cooking in the way of gain or loss (especially of salts), and of physical and chemical changes in the foodstuffs (see p. 421); (2) also that in children about 5 per cent. of the food consumed is undigested, and in adults about 10 per cent.

Supposing a simple diet, Moleschott's figures can be expressed approximately in the following table:—

Article of food	Weight in grammes	Weight in oz.	Proteids	Fat	Carbo-hydrates	Salts	Water
Meat	385	13·5	82·8	21·0	—	3·85	279·0
Butter	70	2·4	2·3	62·0	—	1·89	4·0
Milk	—	—	—	—	—	—	—
Bread	500	17·6	35·0	2·5	276·0	5·6	180·0
Cabbage	225	7·9	4·5	—	11·25	2·25	202·25
Potatoes	250	8·8	5·0	—	51·75	2·5	170·0
Sugar	70	2·4	—	—	67·4	3·5	2·0
Total	1,500	52·6	129·6	85·5	406·4	20·59	837·25

The total weight of food then would be about 1,500 grammes, to which must be added 150 grammes in calculating a diet, as 10 per cent. is undigested, making the total 1,650 grammes.

In this calculated diet, milk and flour may be with advantage used: 500 cc. of milk and 200 cc. of flour would replace 20 grammes of the butter, 120 grammes of the potatoes, and 220 grammes of the bread.

A diet with an excess of vegetable food or consisting solely of vegetable food produces copious soft fæces, containing a large quantity of water;

animal food produces scanty and tenacious fæces. Comparing a mixed diet with a vegetable diet, Schüster found that the fæces in the latter were (when dried) more than double that in the former, while a large amount of proteid of the vegetable diet was unabsorbed (quoted by Förster). Thus:

—	Proteids In food	Proteids Absorbed	In dried fæces
Prisoner, vegetable diet	104	78	70
Experimental prisoner on mixed diet of bread, vegetables, milk, and meat	87	76	30

This would agree with the fact that a large admixture of indigestible matter (cellulose) with the food diminishes the absorption of the digestible foodstuffs—a point to be considered more fully afterwards (see BREAD).

Another result of the excessive or exclusive ingestion of some forms of vegetable food is the amount of gas formed in the intestines, as well as the large amount of undigested matter.[1]

The poor classes use in their diet a larger proportion of carbohydrates than the well-to-do, the excess of carbohydrates taking the place of part of the fat, which is more expensive. With the labourers in Lombardy, Bavaria, and Saxony the carbohydrates vary from 800 to 1,200 grammes in the daily diet, while the proteids are from 140 to 180 grammes.[2] An ordinary labourer will, however, use much less carbohydrates (450 grammes), while the better classes use still less (325 grammes).

Förster[3] gives the following comparison between part of the daily food of a young doctor and a workman:—

—	Fresh meat	Bread	Beer	Proteids In form of meat	Proteids In form of bread	Carbo-hydrates in bread	Carbo-hydrates in beer
	Gr.	Gr.	C.c.	Gr.	Gr.	Gr.	Gr.
Workman	161	412	1,500	35·5	44·3	237·3	78·0
Young doctor	385	150	1,625	84·8	24·8	86·4	84·5

That is, the workman takes 27 per cent. of his proteids in the form of meat, the young doctor 65 per cent.

The diet of the doctor was richer in fat, and the proportion of fat to carbohydrates in his diet was that of 1 : 3·5 in the workman, on the other hand 1 : 5·8.

The total daily amount of food in the two diets may be thus compared:

—	Proteids	Fat	Carbohydrates	Water	Proportion of nitrogenous to non-nitrogenous
Workman	132	81	458	2,916	1 : 5·0
Young doctor	131	95	332	2,975	1 : 4·3

SPECIAL DIETS

The study and correct understanding of diet are important to those able to command every variety of food, but they are of vital importance to communities and bodies of individuals which are supported by the State or in

[1] See Rutgers, *Zeits. f. Biologie*, Bd. xxiv. 1887, p. 351.
[2] Quoted by Förster, *op. cit.* p. 125.
[3] *Op. cit.* Also *Zeits. f. Biologie*, 1873, p. 351.

public institutions. The diet of the soldier and the sailor in peace and war, of the working classes, of prisoners, of those in almshouses, workhouses, and schools, and, lastly, the diet of patients in hospitals, have in this respect to be considered. The diet of the sick is a special subject, and will not be treated here: it is a part of medical treatment.

In considering the diet of such communities of individuals as have been enumerated, not only must the food contain the proper proportion of foodstuffs, such as we have been considering, but the food must be obtainable at a certain price, the object being to provide the most nutritious food at the lowest possible cost. And it is evident that in the case of soldiers, sailors, and the working classes, who are called upon either continuously or at intervals to perform hard work, the question of the energy obtainable by the body from the food supplied is of prime importance. In such classes of men, too, the question of stimulants has to be considered—stimulants to the nervous system, such as tea, coffee, beef-tea, and alcoholic drinks. This last subject will be dealt with under FOOD-ACCESSORIES; at present we are only concerned with the daily amount of food required to preserve the health of communities of men.

Soldiers' and Sailors' Rations

According to Parkes[1] the usual food of the soldier may be expressed as follows:—

Articles	Daily quantity in oz. av.	Water	Proteids	Fats	Carbohydrates	Salts	Total water per food
Meat	12 ($\frac{1}{5}$ bone)	7·20	1·44	0·81	—	0·15	2·40
Bread	24·0	9·60	1·92	0·36	11·81	0·31	14·40
Potatoes	16·0	11·84	0·32	0·02	3·36	0·02	3·72
Other vegetables	8·0	7·28	0·14	0·04	0·46	0·06	0·70
Milk	3·25	0·04	0·13	0·12	0·16	0·02	0·43
Sugar	1·33	—	—	—	1·29	—	1·29
Salt	0·25	—	—	—	—	0·25	0·25
Coffee	0·33	—	—	—	—	—	—
Tea	0·16	—	—	—	—	—	—
Total	65·32	37·78	3·95	1·35	17·08	0·81	23·19

This dietary contains 276 grains of nitrogen and 4,588 grains of carbon. It consists of 112 grammes of proteid, 38·3 grammes of fat, 485 grammes of carbohydrates, and 23 grammes of salts; and the proportion of nitrogenous to non-nitrogenous foodstuffs is as 1 : 4·6.

The diet is, however, *deficient* in proteids, and especially in fat, the proportion of fat to carbohydrate being 1 : 12. This is too small a proportion (see p. 409); so that the diet would be much improved by adding butter or cheese to it. A larger quantity of proteids would also be obtained by substituting peas and beans for the less nutritious vegetables, such as cabbage (returned in the table as 'other vegetables'). Vinegar is also with advantage added to the food.

The mean of the observations of Voit, Artmann, Hildesheim, and Playfair of the soldier's daily diet during peace is 114 grammes of proteids, 45 grammes of fat, and 486 grammes of carbohydrates; a diet closely resembling that of the English soldier. In war the diet would be 138 grammes of proteids, 72 grammes of fat, and 497 grammes of carbohydrates; proportion of

[1] *Pract. Hygiene*, p. 516.

nitrogenous to unnitrogenous foodstuffs being 1 : 4·9 (mean of Hildesheim, Artmann, and Playfair's calculations).[1]

When there is hard work to be done, as in the field or in forced marches, it is advantageous to increase the fat of the diet, and to increase the food-accessories. The increase of fat enables more work to be done, and the food-accessories (tea, coffee, beef-tea, &c.) act serviceably as stimulants to the nervous system.

In the Franco-Prussian war (1870–71) the German soldier had daily:[2]

—	Proteid	Fat	Carbohydrate
Bread, 750 grammes	48	4	345
Meat, 500 grammes	100	15	—
Bacon fat, 250 grammes	11	190	55
1 litre of beer	5	—	—
Total	164	209	400

Each man had also 30 grammes of coffee and 60 grammes of tobacco. Such a diet, rich in fat, is only for the most strenuous exertion.

Diet of the Working Classes

The working classes have to arrange their diet according to the wages they earn, and there is but little doubt that teaching them how to obtain the most nutritious food at the cheapest possible price is one of the great aims of hygiene. A proper dietary for the working classes would mean the improved health of the larger portion of the community, since deficient food itself causes disease and exposes an individual to the dangers of infectious diseases.

In the dietary of the working classes in all parts of Europe there is a deficiency of proteid and of fat and an excess of carbohydrates. The deficiency of proteid in the diet is due to the fact that but little animal food is eaten; fat is deficient from the same cause.

Voit gives in the diet of a workman and workwoman with moderate work the following minimum as the daily need (see also p. 407).

—	Total proteid	Digestible proteid	Fat	Carbohydrate
	Grammes	Grammes	Grammes	Grammes
Man	118	106	54	500
Woman	94	84	49	400

The woman's diet may be reckoned as from three-quarters to four-fifths of the man's.

The actual diets used by the various classes of working men and women differ considerably from Voit's figures; as seen in the following table, taken from C. A. Meinert,[3] the daily food taken is greatly deficient in proteids and fats, a point which has been already mentioned. Although in this table the diets investigated are those of the working class in Germany, almost precisely similar results are obtained from the diet of the English working class.

[1] König, *Zusammensetz. der menschlich. Nahrungs- u. Genussmittel*, 1889, ii. 156. See also C. A. Meinert, *Armee- u. Volks-Ernährung*, Berlin, 1880, i. 286.

[2] König, *op. cit.* p. 160.

[3] *Op. cit.* ii. 171–260.

—	Total amt. of food	Total proteid	Digestible proteid	Fat	Carbo-hydrate	Cost	Kind of food
	Grammes	Gr.	Grammes	Gr.	Grammes	Pence	
Poor workman . .	—	86·0	—	13·0	610·0	—	Potatoes
Berlin workman, obtaining food chiefly from People's Kitchens . . .	—	—	68·0	37·0	290·0	—	Chiefly vegetable food
Seamstress or bookbinder (female) .	846	55·5	47·4	51·4	229·2	$4\frac{1}{4}$	Little meat
Painter in Leipzig .	1,199	86·7	73·3	68·6	366·2	$5\frac{3}{4}$	Mixed food
Cabinet-maker . .	1,281	76·5	60·5	57·2	465·8	$5\frac{1}{2}$	"

All these diets are those of poor workpeople.

The question as to the means by which the poor and the working class can obtain the best food at the lowest price is an important one, but too wide to deal with fully here. C. A. Meinert has treated the subject in a pamphlet entitled 'Wie nährt man sich gut und billig?'[1] Some of his conclusions may be given here. A family is reckoned as consisting of a man, wife, and two children of ten to twelve years of age, all of whom together consume the food of three men. In families earning 15*s*. 6*d*. to 21*s*. a week 60 per cent. of the income may be spent on food—that is, from 9*s*. 6*d*. to 12*s*. 6*d*. a week. In those earning 29*s*. a week half may be spent on food—that is, 14*s*. 6*d*. weekly. For the table showing how the working man can obtain the best food for this money Meinert's pamphlet must be consulted.[2] He reckons that the two poorer families can obtain 100 grammes of proteid, 50 grammes of fat, and 500 grammes of carbohydrate daily; while the family better off can obtain 120 grammes of proteid, 70 grammes of fat, and 500 grammes of carbohydrate—a diet more closely resembling the normal than the first. In the first diet the proportion of nitrogenous to non-nitrogenous foodstuff is as 1 : 5·5, of fat to carbohydrate as 1 : 10; in the second diet the proportions are as 1 : 4·7 and 1 : 7. Fat in a cheap form, such as is now sold as 'margarine,' is a very important addition to the working man's diet.

Diet in Prisons and Workhouses

A proper diet in prisons is one of the great preventives of a large mortality. Besides the evil effects of bad housing, prisoners are especially liable to diseases arising from food. The occurrence of scurvy has by some been ascribed to the deficiency of animal fat in the food.[3] This is perhaps doubtful; but what the diet of prisoners lacks chiefly is animal proteid and fat. The diet is chiefly vegetable, and this may lead to all the trouble which an almost exclusively vegetable (carbohydrate) diet causes. The unpalatable mode of preparation of the food is also a great drawback in the food of prisoners.

In Prussian prisons since 1872, 210 grammes (about 7 oz.) of meat are given weekly; in Belgian, 400 grammes (about 14 oz.); in Pentonville, 117 grammes (4 oz.) are given daily; and in Portland, with hard labour, 175 grammes (6 oz.) is the daily allowance.[4]

The average amount of foodstuffs present in the different food articles

[1] Berlin, 1882. E. S. Mittler u. Sohn.

[2] Abstracted also in König, *op. cit.* i. 165. For England, the amount capable of being spent on food is proportionately less, since the rent is greater on the average than in Germany.

[3] König, *op. cit.* p. 171. [4] *Ibid.* p. 171.

used may be calculated from Richter's results:[1] 108 grammes of proteid, 26 grammes of fat, and 551 grammes of carbohydrate; a diet far behind the minimum diet of a workman with moderate work, which is 118 grammes of proteid, 56 grammes of fat, and 500 grammes of carbohydrate (Voit).

The diet in orphan asylums and other institutions, where the young are cared for, and that in almshouses, where there are the aged poor, must be regulated on the data given on p. 408.[2]

Arrangement of the Daily Food in Meals

But little can be said on this subject here. Although as a rule it is a matter of custom, the meals being taken at the times most convenient to the different classes of society, yet there are a few general considerations which are important. Food is usually taken three or four times daily, the largest meal being taken midday or in the evening. About one-half of the total

—	In 100 parts					
	Water	Proteids	Fats	Carbo-hydrates	Salts	Cellulose
Beef, with little fat (beef steak)	76·5	21·0	1·5	—	1·0	—
Beef (medium fat)	72·5	21·0	5·5	—	1·0	—
Beef (very fat)	55·5	17·0	26·5	—	1·0	—
Cooked meat (roast or boiled)	54·0	27·6	15·45	—	2·95	—
Salt beef (Girardin)	49·1	29·6	0·2	—	21·1	—
Salt pork (Girardin)	44·1	26·1	7·0	—	22·8	—
Fat pork (Letheby)	39·0	9·8	48·9	—	2·3	—
Dried bacon (Letheby)	15·0	8·8	73·3	—	2·9	—
White fish (Letheby)	78·0	18·1	2·9	—	1·0	—
Poultry (Letheby)	74·0	21·0	3·8	—	1·2	—
Egg (deducting 10 per cent. for shell)	74·5	12·5	12·0	—	1·0	—
Human milk	87·0	2·5	4·0	6·0	0·5	—
Cow's milk (sp. gr. 1029 and over)	87·5	3·4	3·6	4·8	0·7	—
Skimmed milk (Letheby)	88·0	4·0	1·8	5·4	0·8	—
Cream (Letheby)	66·0	2·7	26·7	2·8	1·8	—
Cheese	36·8	33·5	24·3	—	5·4	—
Butter	6·0	3·3	88·0	—	2·7 (average)	—
Bread (fine white wheaten)	36·0	7·0	0·5	55·2	1·0	—
Whole-meal bread (Church)	43·4	10·4	0·3	42·7	1·5	1·7
Wheat flour (average)	12·81	12·06	1·36	71·83	0·96	0·98
Whole meal (Atwater)	13·0	11·7	1·7	69·9	1·8	1·9
Barley meal	14·83	11·38	1·53	71·22	0·59	0·45
Pearl barley (Church)	14·7	7·3	1·1	75·8	1·0	—
Rye (average composition)	13·71	11·57	2·08	69·61	1·44	1·59
Rice	13·0	8·0	1·0	76·5	1·0	0·5
Oatmeal (Letheby)	15·0	12·6	5·6	63·0	3·0	—
Maize	14·21	9·65	3·8	69·55	1·33	1·46
Macaroni	13·07	9·02	0·3	76·77	0·84	—
Millet (König), cellulose excluded	12·3	11·3	3·6	67·3	2·3	—
Arrowroot	15·4	0·8	—	83·3	0·27	—
Pea flour (dry)	11·41	25·2	2·01	57·17	2·89	1·32
Potatoes	74·98	2·08	0·15	21·01	1·09	0·69
Carrots (cellulose excluded)	85·0	1·6	0·25	8·4	1·0	—
Cabbage	91·0	1·8	0·5	5·8	0·7	—
Cane sugar	3·0	—	—	96·5	0·5	—

[1] König, p. 171. For further information see *Ueber Massenernährung*, by Baer, Jeserich, and C. A. Meinert, Berlin, 1885. 'Untersuch. der Kost in einigen öffentlichen Anstalten.' By C. Voit. München, 1877.

[2] The food supplied in soup-kitchens and other places for the working classes is treated in C. Voit's work already quoted.

daily food is taken at the chief meal, and about one-third at the next largest meal, which is supper or luncheon or breakfast according to custom. For further details, see Förster's paper in the *Zeitschrift für Biologie* (1873, p. 381).

The taking of a large meal late in the evening leads to digestive disturbances, since during sleep the process of digestion is practically in abeyance, and the presence of food in the stomach leads to bacterial fermentation. Physiologically speaking, the proper times for the man who is busy all day to have his chief meals are at breakfast and at dinner early in the evening; and custom has settled it so. To the working man, however, it is more convenient to have the largest meal in the middle of the day; this is, owing to his hard work, a necessity to him.

The table on page 416 shows the proportion of organic and inorganic foodstuffs in many articles of diet.[1]

From this table the amount of foodstuff present in a diet can be estimated, so as to test the efficacy of a given dietary. Allowance must be made for cooking and for digestibility, as has been previously explained.

Digestibility of Food

No mere calculation of the amount of nitrogen and carbon or the amount of organic foodstuffs in the diet can determine the nutritive value of a diet. To be of use to the organism the organic foodstuffs must undergo a process of digestion before they are absorbed. With the changes (chiefly pathological) which the digestive juices may undergo and thus affect the absorption of food we are not here concerned. But the mixed food itself may be of such a nature as to interfere with its proper assimilation. There are three points which have to be considered under this head.

1. The digestibility of the different organic foodstuffs obtained from the animal and vegetable worlds.

2. The bulk and chemical reaction of the food taken; and the admixture of indigestible matter.

3. The effect of cooking on the food.

1. The *digestibility of the organic foodstuffs*—proteids, fats, carbohydrates.

The proteids obtained from the animal kingdom are more completely digestible than those obtained from the vegetable; so animal fat is also more digestible than vegetable. This is shown in the following table, constructed from results obtained by Rubner:—

Digestibility of Foodstuffs (percentage digested)

—	Meat	Eggs	Milk	Cheese	Rice	Potatoes	Peas	White bread	Black bread	Carrots
Proteid .	97·5	97	92	97	80	75·0	80	78	68	79·5
Fat . .	80·0	95	95	95	—	—	—	—	—	—
Carbohydrates	—	—	—	—	99	92·5	95	99	88	82·0

From this table it is seen that the proteids of meat, eggs, milk, and cheese are far more digestible than those of rice, potatoes, peas, white bread, &c.

The carbohydrates of rice and white bread are the most digestible; while the fat of milk is more digestible than that of meat.

There is a difference, too, in the digestibility of the different kinds of flesh. Using artificial gastric juice, Chittenden and Cummins[2] have found that fish

[1] Compiled from Parkes and König. See also separate sections on food articles.

[2] *American Chem. Journal*, No. 6, p. 5.

is more difficult to digest than meat, white flesh more digestible than dark, raw beef more digestible than smoked (as 100 : 95), while the presence of fat increases the difficulty of digestion. Taking the digestibility of ox-flesh as the standard, 100, veal would be 95, mutton 92, lamb 88, poultry (fowl) 84–86, while fish would be about 90 (although there are great individual differences). These results have been obtained by artificial digestion with gastric juice. They are not so valuable as the results of Beaumont's and of Richet's experiments, which were performed on cases of gastric fistulæ in man. Beaumont, moreover, showed that artificial digestion with gastric juice was much longer in duration than digestion in the stomach. In the following table Beaumont's and Richet's results are given; they are important from a dietetic point of view, for although many of the substances

Table of the Digestibility of Articles of Diet in the Stomach [1]

Food	Preparation	Length of time in stomach till digested, absorbed, or discharged	
		Beaumont	Richet
Schnapps	—	—	30–40 min.
Milk	—	—	30 min., 1 hr.
Rice	Boiled	1 hr.	—
Peas, with bacon fat	—	—	1–2 hr. 30 min.
Baked potatoes	—	—	1 h., 2 h. 15 m., 2·30–3 h.
Eggs, whipped	Raw	1 hr. 30 min.	—
Barley soup	Boiled	1 hr. 30 min.	—
Salmon trout	Boiled	1 hr. 30 min.	—
Flesh	—	—	1 h. 30 m., 2 h. 30 m., 4 h., 5 h. 30 m.
Sago	Boiled	1 hr. 45 min.	—
Spinach	—	—	1 hr. 45 min., 2 hr., 4 hr.
Tapioca	Boiled	2 hr.	—
Barley	Boiled	2 hr.	—
Milk	Boiled	2 hr.	—
Fresh eggs	Raw	2 hr.	—
Cabbage, with vinegar	Raw	2 hr.	—
Soup, with fat and bread	Boiled	—	2 hr.
Rice, with fat	—	—	2h., 2h. 45m., 3h., 3h. 15m.
Milk	Unboiled	2 hr. 15 min.	—
Fresh eggs	Roasted	2 hr. 15 min.	—
Ox-liver	Raw	2 hr. 15 min.	—
Gelatine	Boiled		
Lamb	Broiled		
Hash—meat and vegetables	Warmed		
Beans	Boiled	2 hr. 30 min.	—
Potatoes	Boiled or roasted		
Cabbage	Boiled		
Macaroni and fat	Boiled	—	2 hr. 30 min., 3 hr. 45 min.
Eggs	Soft boiled		
Beef steak	—		
White bread	Baked		
Ham	Boiled	3 hr.	—
Lean beef	Roasted		
Fish	Boiled		
Mutton	Broiled or boiled		
"	Roasted	3 hr. 15 min.	—
Pork	Roasted		
Poultry	Roasted		
Veal	Roasted	4 hr.	—
Brown bread	Baked		
Pork	Salted	5 hr.	—
Eggs	Hard boiled		

[1] Beaumont, *Experiments and Observations on the Gastric Juice and the Physiology of Digestion*, Edin. 1838 (reprint). Richet, *Du Suc Gastrique chez l'Homme et les Animaux*, Paris, 1878.

experimented with contain foodstuffs, such as carbohydrates and fats, which are not digested in the stomach, yet the length of *time* the food remains in that organ is important, for the longer it remains after a certain time the less is it acted upon, and the more likely is it to undergo fermentation, and thus to cause digestive disturbances.

From this table the following conclusions may be drawn :—

(1) That the flesh of animals remains from two and a half hours to five hours in the stomach, the most digestible being lamb, then, in order, beef steak, lean meat, mutton, veal and pork, while fish is equal to mutton in digestibility.

(2) That starchy foods, as rice, barley, and tapioca, do not remain more than two hours in the stomach, while beans, peas, and potatoes remain for two and a half hours, white bread for three hours, and brown bread for four hours.

(3) Richet's results, however, show that, even for the same substance in the same subject, there are varying times in which it remains in the stomach: thus, baked potatoes remained sometimes one hour, sometimes two and a half hours, or even three hours.

The figures quoted, therefore, only give broad differences of digestibility between foods ; digestions differ almost as much as individuals.

The effect of cooking on meat is, that the more tough the process makes the meat, the more indigestible it is. Hönigsberg, comparing the amount of peptone formed by artificial gastric juice from boiled beef and roasted beef, found that in the digested material the proportion of peptone to other nitrogenous substance in boiled meat was as 1 : 2·75, while in roasted beef it was 1 : 1·03 ; from roasted meat, therefore, more peptone is formed than from boiled, raw meat being intermediate in digestibility [1] (see Effect of Cooking).

2. *Bulk and Reaction of Food.*—The division of the daily food into meals has been previously discussed. If too large an amount of the daily food be taken at one meal, the result is not advantageous to the organism. The excess of food throws extra work on the stomach, and continued will end in imperfect digestion and assimilation, with the liability of fermentation of the ingesta, butyric, lactic, acetic, and other fatty acids being formed in excess. This fermentation is especially liable to occur when an excess of vegetable (carbohydrate) food is taken. Not only do the carbohydrates readily split up under the action of bacteria into the different fatty acids, but most vegetable food contains the so-called vegetable acids, acetic, tartaric, citric, &c., either free or in the form of salts, and these simply add fuel to the fire in the stomach. Fats, also, both when neutral and when containing fatty acids, may aid in increasing the acidity of the stomach's contents (due to organic acids), and thus diminish the absorption of foods taken into the digestive tract. Even if this fermentation does not occur, in some cases the food ingested is imperfectly assimilated owing to its admixture with indigestible matter—e.g. cellulose. This result, therefore, occurs when vegetable food is chiefly taken. Thus, with a diet of meat alone, no muscle fibres are found in the fæces, but they are observed when food containing much cellulose is taken with the meat.[2] With brown bread, also, S. Meyer found that 20 per cent. (dried) was passed out of the body, while with white bread only 6 per cent.[3] Rubner has also shown that with the daily use of 960 grammes

[1] *Wiener med. Blätter*, 1882, p. 582.
[2] Förster, *art.* 'Ernährung,' Ziemssen's *Handbuch der Hygiene*, 1882.
[3] *Zeits. für Biologie*, vol. vii. 1871.

(33·8 oz.) of peas 15 per cent. is passed out in the fæces; but with 600 grammes (21 oz.) only 10 per cent. is lost.[1]

Fats when taken in as food are acted upon by the bile and pancreatic juice in the small intestines; for the most part they are emulsified and absorbed by the mucous membrane direct (probably by means of the epithelial cells and the leucocytes), but they are also in part split up into fatty acids and glycerine, the acids uniting with the alkalies present to form soaps which are absorbed. An excess of fat in the diet is passed off in the fæces, and may lead to great digestive disturbance by being split up into fatty acids by means of bacteria. Nothing very definite can be stated as to what is an excess of fat in a diet; what is excess for one individual is readily digested by another, the labourer eats an amount of bacon fat which would nauseate and disturb the digestion of another person not doing so much work.

Berthé's experiments (quoted by Parkes) show that 30 grammes of animal oil added to the ordinary diet were absorbed; but with increasing quantities less was absorbed, and if 60 grammes were continued in the daily diet for some time, 50 grammes passed away by the intestine.

Animal fats are more digestible than vegetable, and it is from animal food and products that the fats of a diet are derived.

The *reaction* of food is also an important point. As a rule it is slightly alkaline, and this stimulates the flow of the gastric juice. If too alkaline, it will tend to neutralise the acid in the stomach, and thus to hinder digestion. The usual mistake is, however, that the food is too acid. The excess of acidity is usually due to the vegetable acids, vinegar, lactic, tartaric, or citric acid. The excess of these acids, especially when a large amount of carbohydrates exists in the food, tends to diminish digestion and absorption of the food, and will if persisted in lead to dyspepsia.

There are other considerations with regard to the digestion of food which may be briefly summed up. *Sleep* diminishes digestion, and, therefore, food ought not to be taken just before going to sleep. Food taken too often also tends to diminish the activity of the digestive juices, and gives no rest to the alimentary tract. According to Ranke, laborious *work* diminishes digestion; but Förster considers that it has no great influence on it. The effect of work on digestion probably, however, differs in the labouring man and in the well-to-do.

3. Preparation and Cooking of Food

Civilised man requires the majority of articles of food to be prepared and to be cooked. And the higher the civilisation, the more is the food elaborated in its preparation, and the more complicated the process of cooking.

1. *Preparation of Food*

This is necessary with those foods which contain a large proportion of indigestible matter. Thus the grain of the wheat, containing internally the starch and proteid food, is separated from its covering, which, although rich in salts, contains much indigestible cellulose. The starch and proteid are also subjected to a process of grinding, and finally are manufactured into bread, which may be considered as a partially digested food (see sub-section Bread). The removal of the grain-covering and the grinding of the grain-contents and the making of bread are all processes which enable the digestive organs to obtain the greatest amount of nutriment from the wheat-grain, a gain

[1] *Zeits. für Biologie*, vol. xvi., 1880.

which more than compensates for the loss of salts contained in the grain-covering.

Other cereals are also prepared and made into flours with the object of removing most of the cellulose. The rougher parts, too, of ordinary vegetables are also removed for a similar reason. Animal foods do not require so much preparation as vegetable—the removal of tendon from meat is the chief point to be attended to.

2. *Effect of Cooking*

The general effect of cooking is to increase the digestibility of food. This is more marked in the case of vegetable food than in that of animal. The cooking also of animal food especially develops 'flavours' in the food; which is an important point, since tasteless food cannot for long be eaten. Flavouring agents are thus often added to increase the savouriness of food (see Food-Accessories). Another result of cooking food is the advantage of taking food hot; cold food has to be raised to the internal temperature of the body, and thus when food is hot less heat is abstracted from the surrounding parts.

Cooking is also a prophylactic measure. The temperature to which well-cooked food is exposed is sufficient to destroy the numerous parasites which may be present in meat, such as the cysticerci of tapeworms, and other worms, and to some extent to destroy any bacteria present. A much higher and more prolonged temperature is necessary to completely destroy the micro-organisms present in food, as the presence of numerous bacteria in the digestive tract testifies.

Vegetables, such as peas, beans, &c., take up during the process of cooking a large percentage of water (see Table, p. 423). They lose a certain proportion of salts, which escapes, if they are boiled in much water. They are best cooked, therefore, with a minimum of water, some fat and salt being added during the process. The chief effect on the organic foodstuffs in the cooking of vegetable food is that part of the proteids (the globulins and albumins) is coagulated by the heat to which they are subjected, the remainder of the proteids ('legumin,' albumose) being unaffected by the heat, while the starch undergoes a complete change. Whether the coagulated proteids are more digestible than the uncoagulated is not at present certain; the heating, however, certainly renders them less liable to be decomposed by the bacteria constantly found in the digestive tract. The starch-grain is in the uncooked state hard and not readily affected by the digestive juices. This is chiefly due to the fact that the grain is composed of starch (granulose) and a little erythrogranulose, which are both enclosed in cellulose coverings. The effect of moist heat is to burst the coats of cellulose, so that the grain swells and the starch is practically set free. By boiling, the starch is converted partly into so-called 'soluble' starch, which, although of the same chemical composition as natural starch, is more readily acted upon by the ferments of the saliva and pancreatic juice. The process of the manufacture of bread must be considered as a partial artificial digestion, since some of the starch of the flour is transformed into dextrine and maltose, the gluten being semi-coagulated.

Animal food is as well digested artificially in the fresh state as when cooked. But cooking is necessary, as it diminishes the time of mastication and increases the savouriness of the food. Unlike vegetable food, animal food loses instead of gains weight during cooking. The loss is chiefly water, but is also due to some fat, salts, and extractives. The following table shows the proportional loss or gain in both kinds of food :—

Table showing Amount of Water in Foods before and after Cooking (Förster)

Fresh Foods	Percentage	*Cooked*	Percentage
Beef (Wolff)	75	Boiled	55–59
		Roast	56–63
Veal (Wolff)	78	Roast	60–64
Wheaten flour	12–14	Bread	36–40
Peas	14	Mashed peas	68–78
		Pea-soup	90
Potatoes	75	Mashed potatoes	78
		Potato soup	91
Cabbage	87	. . . .	85–90

As regards other animal foods, mutton loses in weight rather more than beef during cooking (Letheby).

Loss in Percentage of Weight in Meat during Cooking

—	Boiling	Baking	Roasting
Beef	20	29	31
Mutton	20	31	35

In all forms of cooking large pieces of meat, the first object is to rapidly coagulate the external parts, so that during cooking the juice of the meat should be retained as far as possible. After the coagulation of the external parts, the process of cooking ought to be conducted at a low temperature, not exceeding 160° F. (about 71° C.) Thus, in boiling, the meat ought to be steeped for five minutes in boiling water; in roasting, the joint must be exposed quite close to the fire at first till the outer parts are hard, when it can be removed farther off. The reason why meat should be cooked at a temperature not exceeding 70° C. is that most of the proteid matter of the meat coagulates between 65° and 75° C.; the object is to leave some of the proteid in a semi-coagulated state; but by increasing the heat over 70° C. up to the boiling-point (100° C.) the proteid matters are not only completely solidified, but become, from their hardness, indigestible. Over-heating is, therefore, to be avoided; and the slower the cooking, the better the result. In meat the chief proteid is the myosin of the muscle fibre; there is also the serum of the blood in the blood-vessels and the fibrin of the clot with the hæmoglobin. The myosin is soft just after death, but coagulates soon afterwards, sarcolactic acid being developed as well. This coagulation is called rigor mortis. After a time rigor mortis passes off and the myosin becomes softer again; the meat is then ready for cooking. In hunted and overdriven animals, rigor mortis is early in appearing.

In between the muscle fibres is connective tissue, the collagen of which, during cooking, yields gelatine. The dissolved gelatine partly escapes with the melted fat out of the meat, and the muscle fibres are thus loosened, and rendered more easy to chew. There is also a great loss of salts—more in boiling than in roasting meat.

To sum up the changes that occur during the cooking of animal food: there is a gradual and not complete coagulation of the proteid constituents of the food, the formation of gelatine chiefly from the connective tissues, causing partial disintegration of the tissue, and finally a loss of salts.

Soups and *broths* are best considered as food-accessories, and their effect will be considered under that head. Simple soups contain some of the salts of meat (potassium and phosphates) with added sodium chloride, and the

extractives of meat, together with the aromatic products (sometimes called osmazome). The chief proteid they contain is gelatine derived from the connective tissue of the meat. The aromatic products differ as to whether the broth is made from beef, mutton, chicken, &c. Broths often have vegetables added to them, potatoes, carrots, &c.

For the action of soups and broths see FOOD-ACCESSORIES (p. 477).

THE DISEASES CAUSED BY FOOD

In the preceding pages the data on which food must be taken have been given. It has been shown that not only must there be a certain amount of foodstuffs present in the food, but the food must be in a digestible form and must be properly cooked. If these points are not attended to in a dietary, the food ingested does not perform its functions; it does not support the nitrogen equilibrium, nor does it supply sufficient material for the energy required by the body. The evils that may arise from indigestible food have already been discussed (DIGESTIBILITY OF FOOD, p. 420), as well as those arising from bad cooking. There remain for consideration the bad effects which arise from an excess of food, from a diminution of it, or from diseases communicated by it. This last point will be left for discussion after each separate article of food has been treated.

Effect of an Excess of Food

The effect of over-feeding is more often noticed in the well-to-do than in the poorer classes. In many cases it is simply a habit, but one which leads to serious consequences. A very large excess of food, as we have seen, throws great work on the digestive system, so that the digestive juices cease to secrete and the peristalsis of the stomach and intestines fails to propel the food along. The result of this is a putrefying and fermenting mass in the intestines, which may be large in amount and may necessitate removal by artificial means; or it may be discharged by setting up diarrhœa. Although not commonly of such a severe type, the symptoms of an excess of food are often present in large eaters. Excess of food, therefore, primarily causes *indigestion*, with diminished absorption. But more food than necessary may be absorbed, so that the body gains weight considerably, as Voit has shown, the gain being chiefly in the form of fat. An excess of proteid food (chiefly of animal food) throws, as we have seen, great work on the nitrogenous tissues, so that disorders of the liver and muscles follow; it is considered, too, as one of the factors in the production of gout. And if proteids are taken in excess while the fat and carbohydrate of the diet are in small proportion, the body loses in weight, and this loss is chiefly fat. For although it has been clearly demonstrated that proteids are to some extent a source of fat in the body, they cannot replace the fat in the food; so that when a diet is greatly deficient in fat and carbohydrate, the body draws on its own store of fat, which then gradually disappears. These facts are the explanation of the Banting cure of obesity. The amount of stored-up fat which is destroyed depends, therefore, on the quantity of fat in the food and that in the body.

Other facts are important in the consideration of the effect of an excess of proteid food in the body. These are that the decomposition of proteid in the body is proportional to the intake, even if large quantities be taken; in other words, the excretion of urea augments with the increase of proteid in the food. As a corollary of this, it may be stated that the amount of proteid taken in the body is proportional to the oxygen absorbed in the lungs; for if

there is an excess of proteid, there must be an excess of oxygen (above the normal) to oxidise it.[1]

An *excess of fats and starches* in the dietary tends to produce corpulence and dyspepsia. As we have seen, both the fat of the food and the carbohydrates lead to the deposition of fat in the body. The excess of fat and starch also partly passes away in the fæces, or after absorption some of the starch may pass away in the urine as dextrose.

But little is known of the effect on the body of an *excess of mineral food.* Two points may, however, be mentioned. An excess of potassium salts in the food withdraws sodium and chlorine from the tissues and causes an increased excretion of sodium chloride. This occurs when vegetable food forms the chief part of a diet, since such food contains a large quantity of potassium phosphates. The necessity of sodium chloride for vegetable feeders is thus explained.[2]

An excess of water in the food is not stored up in the body, but is excreted by the urine. The excess over the normal does not simply filter through the body, but it has an effect on the tissues. Thus it tends to produce oxidation of the proteid of the body, and a great excess may even lead to hypertrophy of the heart and fatty degeneration (Buhl, quoted by Förster).

Sodium chloride in excess increases the metamorphosis of proteids in the body.[3]

Effect of Diminution of Food

The complete withdrawal of food, or an insufficient supply of it, leads to the phenomena of *starvation*, with symptoms more or less intense. The complete withdrawal of food leads to rapid wasting of the body, dryness of the mucous membranes, weak action of the heart and of the respiratory system, and on the part of the nervous system to restlessness and delirium, ending in coma. A vigorous adult dies when he loses two-fifths of his body-weight; the young succumb sooner.[4] More important, however, from the point of view of hygiene, than the effect of complete withdrawal of food is the effect of an insufficient supply. In public institutions, prisons, workhouses, orphan asylums, &c., and in the army and navy, where there is a prescribed diet, it is evident that an inadequate supply of food may be fraught with disastrous consequences to large bodies of individuals; and especially is this so with the young, for inadequate nourishment during the growing period leaves its stamp on the organism for life. A general diminution of all the foodstuffs in a dietary, if continued for some time, leads to a general weakening of the body, and so exposes the individual to greater danger from the effects of specific fevers and disorders and from the effects of cold; and especially is this so if work has to be done on an insufficient diet, for in this case work is added to the balance against the individual.

In the previous pages it has been pointed out in what respects the diets of communities living together are deficient. Proteids and fats, especially the latter, are the two chief foodstuffs deficient in their dietaries; and by an increase of the fats of the diet, the health of the communities is undoubtedly greatly improved. It has even been considered that the occurrence of scurvy in prisoners may be connected with a deficiency of animal fat in the

[1] Some of the absorbed proteid may not be oxidised, and thus pass out of the body in the urine; excess of proteid food is thus considered one of the causes of *functional* albuminuria.

[2] See Bunge, *Zeits. f. Biol.* Bd. ix. 1873, p. 104; *ibid.* Bd. x. 1874, p. 111.

[3] Voit, *Einfluss des Kochsalzes u.s.w. auf d. Stoffwechsel.* München, 1860.

[4] For fuller details see works on physiology.

diet.[1] The most that can be said of this, however, is that it may be a part of the history of scurvy.

The effects of a diminution of proteids have already been considered, as well as that of a diminution of fats and carbohydrates in the diet; we may repeat that a diminution of nitrogenous food leads to increased oxidation of the body proteids, i.e. to a loss from the body, in order that the nitrogen equilibrium may be maintained. Fats and carbohydrates are, as has been shown, eminently proteid-sparing foods; therefore the diminution of them in the diet leads either to increased ingestion of proteids in the food or to an increased destruction of proteids in the body.

With regard to *mineral foods*, the effect of this diminution in the diet has been already for the most part discussed in treating of the necessity of the earthy phosphates for the growing organism, and that of sodium chloride to vegetable feeders. The salts of the body exist in two forms, the body-salts or those united with the tissues, and the floating salts or those dissolved in the fluids (Förster). These bear a certain proportion to each other; and if the floating salts are not replaced by the salts of the food, the body-salts are more or less withdrawn from the tissues. In scurvy, for example, there is a diminution of potassium salts in the body; and this is considered one of the factors of the disease. Förster (quoting Felix) says that there may also be excessive excretion of potassium salts in the urine when salt-junk is eaten. Ammonium chloride (and probably sodium chloride) increases the excretion of potassium salts: hence the effect of salt-junk may possibly be explained. On the other hand, the beneficial effect of lime-juice in scurvy has led some to consider that there is a connection between the disease and the ingestion of vegetable acids (citric, tartaric, &c.), although it has been shown that these acids of themselves have no curative powers in scurvy.

Diminution in the amount of *water* leads to storage of water in the body, especially in the muscles, and this, like an excessive ingestion of water, leads to the destruction of body-proteid. The tissues in this watery condition are deficient in activity, and this condition may, according to Förster, be connected with the predisposition of the lower classes to infectious diseases, and in general with a diminished resistance against disease. Scurvy is specially considered after LEMON-JUICE (p. 474).

ARTICLES OF FOOD

ANIMAL FOODS

Articles of diet derived from the various parts of animals are important in several ways. First, they are pre-eminently proteid foods. In them, speaking generally, the proteids exist in large proportion; are, as a rule, easily digested; and are not mixed with substances (such as cellulose) which interfere with digestion.

Second, most of the fat taken as food is derived from animal products. The fat forms part of the various kinds of edible flesh, of milk, and is separated as butter, suet, lard, &c. These fats are more easily digested and more readily assimilated than vegetable fats.

Third, animal foods are one of the sources of sodium chloride, which is necessary for existence. Thus, although the solid tissues themselves contain an excess of phosphates and of potassium over chlorides and sodium, yet in the liquids which bathe the solid tissues, e.g. the liquid round the muscular fibres or the liquid part of the blood in the muscle, and in fact in

[1] König, *op. cit.* Bd. i. p. 171.

all animal liquids, this relation is reversed. The fact has already been referred to, that with vegetable feeders common salt is a necessity which has to be added to the food, whereas with animal feeders it is not so imperatively called for.

Fourth, a great distinction between certain vegetable foods and animal foods is that the latter do not possess to any degree an antiscorbutic power. It is true that in the 'Eira' Arctic Expedition, fresh meat (walrus) was found to prevent an outbreak of scurvy in the men; but, as a rule, it may be said that fresh meat is not to any extent antiscorbutic.

It may again be pointed out that cooking is all-important for animal foods, not only to render the food more digestible, but also to destroy parasites (see Cooking of Food, p. 421); and this remark applies to the boiling of milk as well as to the cooking of the solid animal foods.

Milk (and to some extent liver) is the only animal food which may be considered a carbohydrate food.

MILK AND MILK-PRODUCTS

The chief forms of milk and milk-products may be arranged as follows:—

1. *Milk* from the cow, buffalo, ass, goat, and mare; human milk.
2. *Milk-products.*
   Unaltered from natural milk:—
   - *a.* Skimmed milk, including various forms.
   - *b.* Cream.
   - *c.* Butter.
   - *d.* Condensed milks.

   Altered from natural milk by decomposition or fermentation:—
   - *e.* Cheese.
   - *f.* Koumiss and Képhir.
3. *Prepared milk-foods* for infants and invalids.

Composition of different Milks

All forms of milk are emulsions of fat containing proteids, carbohydrates, and salts in solution in water. In the following table (summarised from König) the average composition of milks is given in percentages, i.e. in 100 cubic centimetres is contained the dried weight of foodstuffs in grammes stated.

Composition of Milks in 100 *parts* (*average of many analyses*)

—	Sp. gr.	Total solids	Proteid Casein	Proteid Albumin	Fat	Lactose	Salts	Water	Proportion of nit. to non-nit. as
Mare's	1035	9·22	1·24	0·75	1·21	5·67	0·35	90·78	1 : 3·4
			1·99						
Ass's	1023–1035	10·36	0·67	1·55	1·64	5·99	0·51	89·64	1 : 3·4
			2·22						
Human	1027	12·59	1·03	1·26	3·78	6·21	0·31	87·41	1 : 4·4
			2·29						
Cow's	1032	12·83	3·02	0·53	3·69	4·88	0·71	87·17	1 : 2·5
			3·55						
Goat's	1032	14·29	3·20	1·09	4·78	4·46	0·76	85·71	1 : 2·0
			4·29						
Buffalo's	1032	18·59	5·85	0·25	7·47	4·15	0·87	81·41	1 : 1·9
			6·10						

The kinds of milk important from the point of view as food to man are human milk and cow's. They differ in the following particulars: as regards the proteids, human milk differs from cow's in having less casein but more albumin; the fat is about the same in both kinds, there is more sugar in human than in cow's milk, but less salts.

The salts of milk are composed of all the constituents necessary to the growing organism: calcium, sodium, potassium, chlorides, phosphates, and iron. As in most foods, the potassium and phosphates are in excess. The calcium phosphate present aids in the solution of the casein. Besides the mineral salts, there are organic compounds, such as urea, creatin, sarkin, &c., which are included under the term *extractives*.

Percentage of Salts in the Ash of Human Milk.[1]

NaCl	10·73
KCl	26·33
KHO	21·44
Ca	18·78
Mg	0·87
P_2O_5	19·0
$Fe_2P_2O_5$	0·21
H_2SO_4	2·64
Silica	Trace

Variations in the Composition of Cow's Milk

1. *Time after Calving.*—The first milk, or colostrum, varies greatly from that subsequently secreted. It contains, like the colostrum of human milk, a large quantity of serum-albumin, a larger quantity than normal of casein; while the lactose is diminished. The mean of many analyses given by König is 74·67 per cent. of water; 4·04 of casein, 13·6 of albumin; 3·59 of fat, 2·67 of lactose, and 1·67 per cent. of salts.

After the colostrum, the milk varies slightly in quality, being at first mixed with the colostrum.

Up to the second month after delivery, the casein and fat are increased. From the tenth to the twenty-fourth month the casein diminishes, while the fat becomes less from the fifth to the sixth month, and the tenth to the eleventh. The sugar is diminished during the first month, but increases from the eighth to the tenth month. The salts increase up to the fifth month, after which they steadily diminish.[2]

2. *The Race of the Cow.*—Some milks are rich in fat, others in casein.

3. *The Kind of Feeding.*—Fodder rich in carbohydrates, such as beet, carrot, &c., causes an increase of the amount of sugar in the milk. An increase of proteids in the diet causes an increase of the casein, while the fat is not much influenced.

The age of the cow and the number of pregnancies also affect the composition of the milk.

Milk as an Article of Diet

Milk is the chief diet for children up to the age of eighteen months or two years: its value has already been partly pointed out (p. 410). It is almost completely digested in the intestines: when exclusively used for adults, it

[1] The composition of the ash of cow's milk is similar.

[2] Landois and Stirling's *Physiology*, 3rd ed. p. 347.

leads to constipation. When digested either by pepsin or the pancreatic juice, milk clots, the casein being precipitated in large curds. This is the first stage of digestion; the curds are then changed into albumoses and peptones by the ferments, a bitter substance being formed which makes the peptonised milk unpleasant to the taste.

For infants, human milk contains the nitrogenous and the non-nitrogenous organic foodstuffs in the right proportion, viz. 1 : 4·4; and so does mare's or ass's milk. But in cow's milk the proportion is 1 : 2·5, and therefore cow's milk is not a perfect food by itself. If the non-nitrogenous organic foodstuffs are increased, as by adding sugar or arrowroot to the milk, it then becomes a very important food. Such additions are made for young children and in the dietary of adults.

As cow's milk has often to be substituted for human milk in the rearing of children, it is important in many instances to artificially bring the composition of the milk to that of human milk. This is done in the following manner: the cream is separated from a pint of milk, and the casein of one-half of the skimmed milk coagulated with a small quantity of rennet and strained off. To this whey the cream which has been removed and the rest of the skimmed milk is added. The composition of this artificial human milk varies: it contains on the average a little over 2 per cent. of proteid, 4·5 per cent. of fat, 5 per cent. of lactose, and 0·6 per cent. of salts. In feeding infants, the cow's milk has to be diluted; for, containing much casein, this forms large clots in the stomach, which cause indigestion. *Dilution* diminishes the size of the clots of casein, and in many instances this is sufficient; lime-water or barley-water added is also beneficial in some cases. After dilution, the addition of sugar to the cow's milk is necessary to bring it nearer to the standard of human milk. Spiegelberg [1] says that during the first three or four weeks of life two parts of water must be added to one part of milk; after the third and fourth months, more milk may be given, till from the fifth and sixth months the child may have undiluted milk. The milk has often to be more diluted than this. To each litre of diluted milk thirty grammes of milk-sugar must be added.

Percentage Composition of diluted Milk and added Lactose

—	Proteid	Fat	Sugar	Salts	Water	Proportion of nit. to non-nit. as
Cow's milk with equal parts of water .	1·77	1·85	5·44	0·35	92·73	1 : 4
Cow's milk with two parts of water .	1·18	1·23	4·63	0·23	90·59	1 : 4·8

During the first half-year a child weighing 5 to 6 kilogrammes consumes 1 to 2 litres of mother's milk daily, i.e. in a litre nearly 30 grammes of proteid, 39 grammes of fat, 62 grammes of sugar, and 3 grammes of salts. To obtain a similar amount of foodstuffs, it would require to take daily 3 litres of milk diluted with 2 parts of water; it would, however, be then receiving nearly 140 grammes of lactose.

Ass's milk is nearest in composition to human milk, and is sometimes used as a substitute: its chief deficiency is in the amount of fat. Mare's milk contains less proteids and fat than ass's milk; while goat's milk and buffalo's are very rich in fat, the former having a peculiar smell.

[1] *Midwifery, New Syd. Soc.'s Trans.* vol. i. 1887, p. 329.

One litre of cow's milk (35 ounces) contains—

35·5	grammes of	proteid
36·9	,,	fat
48·8	,,	lactose
7·1	,,	salts
and 871·7	,,	water

Such a quantity, then, contains half the daily quantity of proteids, and more than half the daily quantity of fat necessary for a child from six to fifteen years of age.

An adult would require 5 litres (about 9 pints) of milk daily to obtain the requisite amount of proteids, 130 grammes; and then he would be taking 180 grammes of fat, and only 240 grammes of carbohydrates. Milk, being easily digested, is a useful article of diet in certain cases of mal-assimilation of food or in old age.

Diseases Caused by Milk and Milk-products

1. Milk after standing for some time becomes sour and coagulates. This effect is due to the *bacillus acidi lactici*, so named because lactic acid is the chief product of its activity, carbonic acid being at the same time formed. Such milk is a fruitful source of digestive trouble in infants, and is unfit for food. It leads to vomiting, flatulence, and diarrhœa. To sour milk are to be ascribed many of the cases of infantile diarrhœa.

Blue milk is not common. The colouration is due to the growth in the milk of the *bacillus cyanogenus*, which is itself colourless, but imparts a blue colour to the milk, intensified if the lactic acid fermentation also occurs. The blue colour was at one time ascribed to the eating of certain meadow-plants. Blue milk causes irritation of the stomach and intestines, producing diarrhœa.

Many micro-organisms produce coagulation of milk, e.g. the *bacillus butyricus* of butyric acid fermentation. Other fungi turn the milk bluish black or green. *Yellow* milk is due to *bacterium synxanthum*, which makes the milk first acid, then strongly alkaline. *Red* milk is due to *micrococcus prodigiosus*; the change was formerly ascribed to disease of the cow. Both the colouring matters of yellow and red milks are related to aniline. Milk may also become *stringy* or ropy, due to the action of bacteria.

2. Besides these visible changes in the milk, occurring after the milk has been drawn, there are others which are present in the milk when drawn.

a. Many substances are excreted in the milk when given to the mother or taken in with the fodder of the animal. Iodides, arsenic, antimony, mercury, carbolic and salicylic acids, rhubarb, and opium may thus be present in the milk and affect the child. Castor oil also when taken by the mother acts, as is well known, as an aperient to the child.

Turnips, diseased potatoes, and other plants in the fodder of the cow may impart an unpleasant aroma to the milk without altering its efficacy as an article of diet. But some other kinds of fodder produce poisonous milk, owing to the excretion of poisonous substances. For example, the milk of goats which have eaten colchicum or Euphorbiaceous plants produces poisonous symptoms, including diarrhœa. The milk from cows feeding on wort is injurious.[1] The *Rhus toxicodendron* also produces poisonous milk; children partaking of it suffering from weakness, vomiting, and constipation.

[1] Förster, *op. cit.* p. 159.

The plant also causes 'trembles' in the cows. The poison is destroyed by boiling the milk.

b. The milk may be affected by the diseased condition of the cow. The *mammary gland* of the animal may be affected with disease; it may be

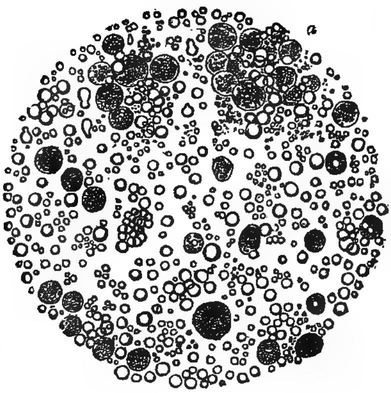


FIG. 87. Human milk with colostrum corpuscles (*a*). (Carpenter.)

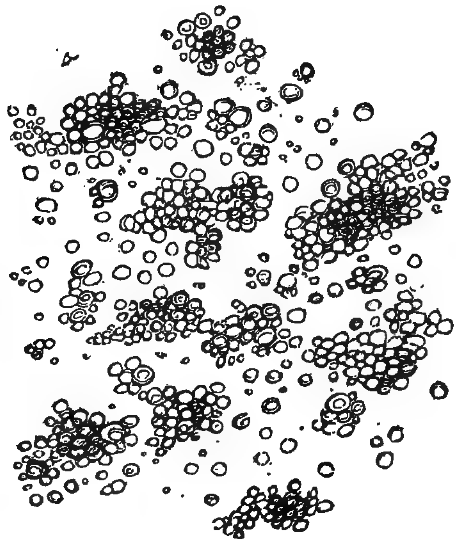


FIG. 88.—Milk in foot-and-mouth disease, showing clustered milk corpuscles and bacteria (early stage).[1]

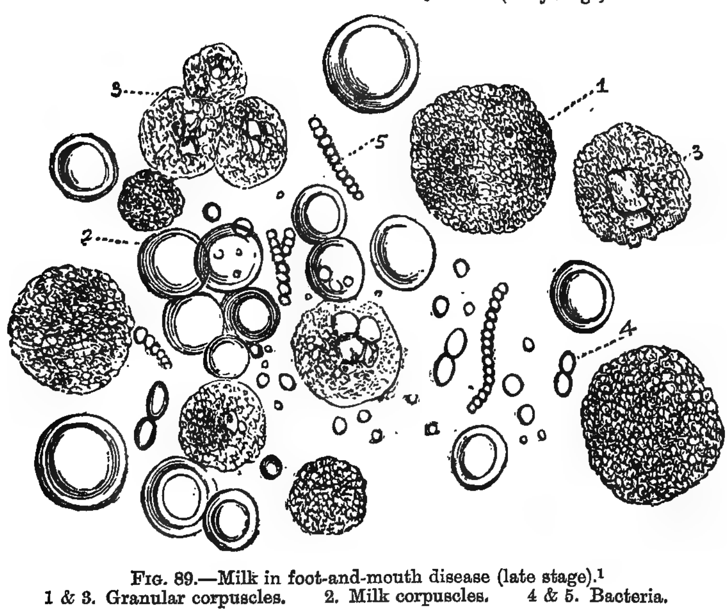


FIG. 89.—Milk in foot-and-mouth disease (late stage).[1]
1 & 3. Granular corpuscles. 2. Milk corpuscles. 4 & 5. Bacteria.

acutely inflamed (acute mastitis) or chronically (interstitial mastitis), or it may be tubercular. Pus may then be present in the milk as well as tubercle bacilli. The analysis by Fürstenberg of milk from a cow with interstitial hyperæmia of the mammary gland shows a varying composition. In one

[1] Figs. 88 and 89 are taken from the *Lancet*, vol. ii. 1869, p. 590.

animal the milk contained 5·78 per cent. of proteid, with only a trace of fat and lactose; in another the proteid was still higher—8·89 per cent., while the fat and salts were increased and the lactose below normal; in a third the composition of the milk was within the normal limits. In acute mastitis the casein, fat, and sugar were found diminished, while the albumin was greatly increased—5·3 per cent. (Fürstenberg, quoted by König).

In *foot-and-mouth disease* (*eczema epizootica*) the milk varies in composition greatly, and under the microscope pus and blood corpuscles are often seen (figs. 88 and 89). The following analyses (quoted by König) show this:—

Composition of Milk in Foot-and-Mouth Disease

—	Water	Casein	Albumin	Fat	Lactose	Salts
Acute stage . . .	87·70	3·90		3·90	3·81	0·69 } Lassaigne
During convalescence .	90·60	2·85		2·30	3·02	1·23 } Lassaigne
On 2nd day of disease .	79·90	—	14·38	5·01	—	0·71 } Wynter Blyth
On 4th day of disease .	83·85	3·47		7·80	4·67	0·21 } Wynter Blyth
On 14th day of disease .	83·88	—	11·48	3·96	—	0·68 } Wynter Blyth

The composition of the milk, therefore, varies greatly; the chief point in Wynter Blyth's analyses is the great excretion of serum-albumin in the milk. The milk from cows suffering from foot-and-mouth disease may, according to some, cause disease in the human being, and especially in the case where the udder of these cows is in an aphthous condition.[1] The symptoms are limited to the mouth, and consist in aphthous ulceration, with hyperæmia and the formation of a membrane, and swollen tongue (Parkes). The milk is fatal to calves and to young pigs.[2]

Tuberculosis in cows (*Perlsucht*) affects the milk, and may lead to the same disease in man. A distinction must be drawn between the milk from cows with tubercular udders and that from animals with general tuberculosis only, since, according to Baug, tubercle bacilli are rare in milk unless the udder is tuberculous. Animals can be given tuberculosis by feeding them with milk from tubercular cows (Bollinger). Boiling the milk is a preventive measure, as the tubercle bacilli are destroyed by heat. The composition of the milk varies from the normal. If the glands are themselves tubercular the secretion is strongly alkaline. The mean of three analyses by Storch[3] of milk taken at different times from the same cow is 87·52 per cent. of water, 5·58 per cent. of proteid, 4·29 of fat, 1·65 of lactose, and 0·96 of salts. Lehmann, however, found in the milk of a tubercular cow only a small proportion of casein and fat, and Förster[4] in another case found a large quantity of proteid and fat, but only 1·06 per cent. of lactose—a result more closely resembling Storch's analysis.

The milk from cows suffering from *cattle-plague* (*Rinderpest*) is altered in composition. According to Monier's analyses it contains a large proportion of casein (8·2 to 10·12 per cent.), a trace of albumin (0·49 to 0·85 per cent.), a large proportion of salts (1·12 to 1·59), while in the late stages of the disease there is a great diminution in the amount of fat and sugar.

Power and Klein have described a disease of cows which leads them to think that *scarlet fever* may be transmitted by the milk to man. The organisms found in scarlet fever and in the cow disease (at Hendon) were described as identical.[5]

[1] Förster, *loc. cit.* [2] *Lancet*, vol. ii. 1869, p. 590.
[3] Quoted by König, *op. cit.* p. 332. [4] *Op. cit.* p. 161.
[5] For the controversy on this subject see the medical journals, 1888–9.

3. After being drawn the milk may be infected, and it is in this way that milk has been supposed to be the vehicle for the poisons of typhoid fever and diphtheria and many cases of scarlet fever. Cases of these diseases have been present near the dairy, and the milk has become infected either directly or by the use of water impregnated with the poison.

One of the best prophylactics against diseases arising from the use of milk is *boiling the milk*; this ought always to be done in summer and winter.

Preservation of Milk

Cow's milk may be preserved by boiling, and tightly corking the vessel. The preservation is, however, only temporary. Antiseptics may be added after boiling, such as salicylic acid, boric acid, boroglyceride, sulphurous acid. Of these the most innocuous are boric acid and boroglyceride.

The best forms of preserved milks are the concentrated forms—the condensed milks, with or without the addition of sugar, and the dried milk.

In condensed milk without the addition of sugar the preparation is sold in tins, and the milk does not keep for very long after the tin is opened. The sweetened condensed milks keep for a month or longer after opening.

Scherff's preserved milk is condensed to one-half or one-third of the original bulk.

Percentage Composition (average) of Condensed Milks[1]

—	Water	Proteid	Fat	Lactose	Cane-sugar	Salts	Proportion of nitrogenous to non-nitrogenous food-stuffs as
Condensed milk with added cane-sugar	25·61	11·79	10·35	13·84	36·22	2·19	1 : 5·2
Do. without added sugar	59·00	11·92	12·42	15·48	—	2·18	1 : 2·3
Scherff's condensed milk	72·87	8·20	6·62	10·63	—	1·68	1 : 2·1

Some preparations of condensed milk contain more sugar than the average given above.

Sweetened condensed milk is much used as an infant food, especially among the lower classes. For very young children it is diluted to the strength of one teaspoonful to four or five tablespoonfuls of water. According to J. Förster a child of four to five months of age ought to have daily 214 grammes of condensed milk, i.e. 7½ ounces. This would (on an average) contain as the daily food 21·3 grammes of proteid, 18·4 grammes of fat, and 98·2 grammes of carbohydrate, with about 5 grammes of salts. The proportion of nitrogenous to non-nitrogenous foodstuffs is in this diet 1 to 5·4, which is a great deal too high. The amount of sugar is excessive and the fat deficient.

Average Composition[2] *(percentage)*

—	Water	Alcohol	Lactic acid	Carbonic acid	Lactose	Proteid	Fat	Salts	Glycerine
Koumiss from mare's milk	90·44	1·91	0·91	0·857	1·77	2·24	1·46	0·22	—
Koumiss from cow's milk	89·20	1·14	0·55	0·86	4·09	2·66	1·83	0·43	0·16
Képhir	91·21	0·75	1·02	—	2·4	3·49	1·44	0·68	—

Other preparations of milk are koumiss and képhir. These were both originally prepared from mare's milk, by a peculiar process of bacterial fermentation, in the Caucasus; koumiss is, however, now made from cow's

[1] König, *op. cit.*

[2] From König, *op. cit.*

milk as well. They both contain free carbonic acid and lactic acid, with some alcohol. In képhir the casein is partially changed into albumose and peptone. Both preparations are used as food in phthisis and in cases of vomiting.

Examination of Milk. Adulterations

Milk is so largely used as an article of diet, and so important a food not only to the young but to adults, that a regular and good milk-supply to large towns is largely mixed up with the well-being of the inhabitants.

Although the milk from different cows varies in composition, yet the admixture of the milk given by a herd averages the composition within certain limits. In investigating the milk-supply from any particular locality it is important to determine the number of cows in a herd, the age and race, the kind of fodder, the health, and the time of milking.

A single cow will give on the average 9 to 14 litres of milk in the twenty-four hours; but the quantity may be less (in poorly-fed cows) or more (soon after parturition). If the cow gives less than eight litres a day it is best not to use the milk for consumption. Milk also ought not to be consumed until the expiration of a fortnight after calving. The necessary regulations regarding the animals on a dairy farm come under several headings. The fodder is important. All those substances that impart a bad taste to the milk ought to be withheld: such as brewers' wort, turnips, and decomposed food. Carrots up to a certain quantity are allowable; but the chief food ought to be rape-seed cake, bran, corn, hay, and grass. A regular inspection of the animals is necessary, to see the quantity of milk given by each cow, and to investigate the health of the animals. The milk of sick and weakly animals must be excluded, as well as that from animals with diseased udders—mastitis or tuberculosis. Strict cleanliness in the milking is necessary, and the mixed milk of the herd is, with advantage, strained to remove gross impurities, or passed through two gravel filters of different coarseness, as is directed by the Copenhagen Milk Supply Company.

Microscopical Examination.—Pure milk under the microscope shows a great quantity of highly refractive oil globules floating in a clear liquid. These oil globules are large, medium-sized, and minute; they vary in diameter between 0·017 millimetre and 0·01 millimetre. In old milk they are not so well defined as in fresh milk.[1] Colostrum (the first milk after delivery) has a very different appearance under the microscope (fig. 87). It contains very large oil-globules, some epithelial scales, granular matter, and, most characteristic of all, granular corpuscles, the largest of which are about 0·05 millimetre in diameter. Good milk may contain some of these corpuscles, but they ought to be very few in number. The fat globules of milk are not dissolved by ether alone, but are completely soluble if milk is shaken up with ether and potash.

Diseased milk sometimes shows abnormal constituents. Pus corpuscles may be seen in abundance; also red corpuscles. Bacteria may be seen without the aid of staining; but if the appearances are doubtful, they may be stained for fifteen minutes with a 2 per cent. watery solution of methylene blue after drying a drop of milk carefully on a cover-slip, washing off the excess of colouring matter under the tap, and examining under the microscope after mounting on a slide with a drop of water. If necessary the fat may be removed from the dried specimen before staining by washing it with ether.

[1] Hilger, *op. cit.*

To decide the kind of bacteria present, cultivations must be made. Staining in this way is also the best method for showing pus corpuscles. For tubercle bacilli the cover-glass is prepared in the same way, and stained for five minutes in warmed carbolic-fuchsin solution (Ziehl's solution); decolourised in 25 per cent. sulphuric acid, washed in water, stained with methylene blue, washed again, dried, and mounted in Canada balsam. Several preparations must be made.

Variations in the Composition of Milk

Specific gravity	1028–1034
Water	85–88 per cent.
Casein &c. (albumin, 0·05–4·5)	2·5–5 „
Fat	2·7–6 „
Lactose	3·5–6 „
Salts	0·5–0·75 „
Total solids	9·2–17·75 „

On the average, however, the total solids should not be below 12 per cent.

Reaction of Milk.—Milk is normally alkaline (slightly). London milk is usually, however, slightly acid; this is due either to change in the milk in the milk ducts or after it has been drawn. Strong acidity means lactic or butyric acid, the presence of which may be demonstrated by shaking the milk with ether, which dissolves them; the casein is usually coagulated in such milks. Strong alkalinity may mean added sodium bicarbonate or diseased milk.

Adulterations of Milk

1. Water may be added to the milk.
2. A common adulteration is removing part of the cream and adding water to bring the specific gravity up to the normal; or removing the cream from the evening milk and adding the morning milk.
3. Sodium bicarbonate, borax, boric acid, and salicylic acid are added to preserve.
4. Starch, flour, gum, dextrine may be added.

1. An excess of water may sometimes be detected by taking the specific gravity. This is done by means of a lactometer (an accurate hydrometer), and must be done at 15° C.; or, if at other temperatures, the result must be corrected for 15° C.

In good milk the specific gravity is from	1028–1034
In creamed milk the specific gravity is from	1033–1037
In half-creamed milk the specific gravity is from	1031–1034

This method, however, has to be supplemented by the following methods and by estimating the total solids.

To estimate the total solids, take 10 grammes (weighed) of milk, add two drops of acetic acid and 2 c.c. of alcohol, and evaporate to dryness in a water-bath, afterwards keeping for some time at 105° C. The total solids ought not to be below 12 per cent.

2. The detection of deficiency in cream is the most important point in the examination of milk.

The cream may be estimated in a cylindrical vessel, graduated in 100 parts (creamometer). Fresh milk is poured into the vessel up to the graduation, and kept for twenty-four hours at a temperature of 10°–15° C. The cream floats on the top, and ought to measure 10–15 volumes per cent. In half-creamed milk the amount is 5–6 volumes. The cream may be removed,

and the specific gravity of the underlying watery liquid (containing salts, lactose, and casein) may be taken. The specific gravity ought to be 2·5°–3·5° higher than that of the whole milk. If less than 2·5° higher it shows admixture of water (Hilger).

Fat in good milk ought not to be less than 3 per cent., and in creamed milk not less than 1 per cent.

The amount of fat may be determined in the following manner:

Ten grammes (weighed) of milk are mixed with 20 grammes of burnt gypsum, and evaporated to dryness in a water-bath. The fat in the residue is extracted by ether, and the ethereal solution after removal is evaporated, and the residue dried at 105° C. and weighed.

3. Sugar is estimated by titrating with Fehling's solution; 10 c.c. of this solution is decomposed by 0·0676 gramme lactose.

4. In the detection of starch, &c., 50 c.c. of milk is diluted with 200 c.c. of water, heated, and alcohol is added to coagulate the proteid. The mixture is then filtered, and the filtrate evaporated to half its bulk (or less). In this filtrate great alkalinity usually means sodium bicarbonate.

Starch is shown by the blue colour with iodine; and if starch is absent, dextrine is indicated by the red colour with iodine. Gum is precipitated from the filtrate by alcohol. Salicylic acid is shown by the violet colour on the addition of perchloride of iron.

The serum-albumin may be estimated in the whey after clotting a measured portion of the milk by rennet. A measured quantity of the filtered whey is precipitated by excess of alcohol, the precipitate collected, washed with ether and alcohol, dried and weighed.

MILK PRODUCTS:—*Skimmed Milks; Cream; Butter*

The cream may be removed from the milk by allowing the milk to stand, or by the centrifugal machine. The liquid remaining is skimmed milk, and is a useful article of food. The composition of these products is shown in the following table:—

Composition in 100 parts

—	Water	Proteids	Fat	Lactose	Salts	Lactic acid
Cream	68·82	3·76	22·66	0·59–5·52	0·53	—
Centrifugalised milk[1]	90·60	3·06	0·31	5·29	0·74	—
Skimmed milk	90·12	4·03	1·09	4·04	0·72	—
Buttermilk	90·6	3·8	1·2	3·4	—	0·3[2]
Butter (English)	13·33	1·06	84·40	—	1·21	—

Cream varies in composition.

Specific gravity	1004–1025
Fat	from 18–70 per cent.
Water	„ 20–76 „

It is adulterated with albumin, starch, and sometimes other insoluble substances. The methods of examination are the same as those for milk.

Cream may be utilised for feeding the child when the casein of milk disagrees. According to Kehrer and Biedert (quoted by Spiegelberg[3]), 125 c.c.

[1] The composition of skimmed milk is closely similar to that of centrifugalised milk.

[2] König, quoted by Förster. Buttermilk varies greatly in composition: it often contains much less fat (0·5 per cent.) and more lactic acid than in the analyses given.

[3] *Op. cit.* p. 331.

of cream must be mixed with 375 c.c. of boiled water in which 15 grammes of milk-sugar have been dissolved. The proportion in English measure is, cream one ounce, water three ounces, milk-sugar one drachm. The mixture contains 1 per cent. of casein, about $5\frac{1}{2}$ per cent. of fat, and about 4 per cent. of sugar; if necessary, the amount of fat can be reduced. An eighth of a litre ($4\frac{1}{2}$ ounces) is to be given every two hours.

Buttermilk and skim milk are useful articles of diet; they may be thickened with carbohydrate (starchy) food, and are serviceable in the dieting of children and of dyspeptics.

An alkaloid, tyrotoxicon, may be present in decomposed cream and cause serious symptoms of poisoning (Vaughan).

Butter

Butter, the fat of milk, is one of the most important articles of diet, being an easily assimilated form of neutral fat. The well-to-do take a large part of their fat in this way. It consists chiefly of neutral fats, mixed with water and a small proportion of casein and salts (see above). These fats are the glycerides of oleic, palmitic, and stearic acids, with smaller quantities of the glycerides of myristic and butyric acids, and of the higher fatty acids, such as caproic, caprylic, &c. When rancid it contains free fatty acids with the decomposition products of glycerine (acrolein, &c.) and is apt to cause or to aggravate the symptoms of acid dyspepsia. The average amount taken daily is about 28 grammes (one ounce), which contains about 24 grammes of neutral fat, or about two-fifths of the daily allowance of fat for an average man in moderate work.

Variations in Composition.—The water in fresh butter is from 6 to 30 per cent., the fat 70 to 95 per cent., and the casein, lactose, and salts (which may be reckoned together) from 0·9 to 6 per cent.

The greatest amount of water ought to be 12 per cent.; quantities above this represent water added to give weight. The casein, lactose, and salts ought not to be more than 2 per cent., and the fat must be at least 86 per cent.

In fresh butter the added chloride of sodium should not be more than 0·5 to 2 per cent. Strongly salted butter contains about 8 per cent. of added salt, and 16 per cent. of water. Salt is almost absent from French butter, and boric acid is added as a preservative.

Adulterations of Butter.—Butter is generally coloured by such substances as saffron, curcuma, annatto, &c. No deleterious effect can, however, be ascribed to these additions.

Insoluble substances may be added to give weight, such as potato-starch, chalk, gypsum, and sometimes alum and free alkalies.

Foreign fats are the most important addition: tallow, lard, artificial butter, palm oil, cocoa-nut oil, and rapeseed oil.

Method of Examination of Butter.—The *smell and taste* of butter are characteristic. On saponifying with alkalies it gives the characteristic smell of the compound ether of butyric acid, which is not perceived if the product saponified is artificial butter.[1]

The *amount of water* present in butter may be estimated by drying the butter at 110° C., and weighing before and after. A very small quantity of water is suspicious of foreign fat (Angell, quoted by Parkes).

The *amount of fat* is estimated by dissolving it in ether, evaporating the ether solution, drying and weighing. After dissolving the fat in ether, the

[1] A. Hilger, *Ziemssen's Handbuch der Hygiene*, Th. 1, Abth. 1, 1882, p. 237.

residue consists of *casein, lactose, and salts.* The casein is estimated by washing the residue, drying, and weighing ; it ought not to be more than 1·06 per cent.

The *added chloride of sodium* is estimated by titrating with the standard solution of silver nitrate, after solution of the fat in ether.

Detection of gross impurities in butter: starch, gypsum, sulphate of barium, &c.

Hilger recommends the following method. To from five to ten grammes of butter add twice the volume of water with a little alcohol, and keep the mixture at the melting point of the butter for a short time. The fat separates from the watery substratum and may be removed. The watery layer may contain in solution the added colouring matter, borax, free alkali, alum, and sodium chloride, and traces of salicylic acid. The insoluble impurities sink to the bottom, and may consist of starch, barium sulphate, chalk, &c. The microscope detects the starch grains, as does a solution of iodine, and chemical tests detect the other insoluble impurities.

Detection of the Admixture of Foreign Fats.—Foreign fats, chiefly animal, such as beef and mutton fat and lard, are the most important adulterations of butter.

There are several methods for the detection of these impurities.

1. *Specific gravity* (Bell's method).

The fat is first melted at 100° F., and the specific gravity estimated by weighing in a specific-gravity bottle.

The specific gravity of butter ought never to be below 910; as a rule it is between 911 and 913 ; if adulterated butter, it is 902–904 ; if artificial butter, it is 859 ; and if lard, beef fat, and mutton fat, it is 860–862.

2. *Determination of the melting point of the fat.*

The fat is first separated from the other constituents of the butter, and the melting point determined by gradually heating the fat in a water-bath. The following table of melting points is given by Hilger :—

	Melting point
Butter (dehydrated)	30·8°–35°C.
Butter fat	32·5°–36°
Lard	41°–42°
Beef fat	42°–44°
Mutton fat	47°–51°
Artificial butter	28°–31°
Palm oil	30°–44°
Cocoa fat	28°–35°

Parkes attached great importance to the determination of the melting point, and variations from the average are sure indications of admixture of foreign fats, especially beef fat and lard.[1]

3. The *microscope* may indicate foreign fats by discovering crystals of margaric and stearic acids. Pure butter shows only oil globules. The microscopic tests require to be supplemented by the other tests mentioned, and by the following :—

4. *Determination of the fixed (insoluble) fatty acids* (Hehner).[2]

This method is based on the fact that the fixed fatty acids obtainable from butter differ in amount from those obtainable from other animal fats.

[1] See Parkes's *Pract. Hygiene*, 7th ed., p. 307, where a useful table is given of the temperatures of fusion and solidification of different fats.

[2] *Chem. News*, 1877.

From butter, 86·5–88 per cent. of fixed fatty acids is obtainable; from other animal fats, 95·28–95·8.

To 5 grammes of butter fat 50 c.c. of alcohol containing 2 grammes of caustic potash (KHO) is added, by which the fat is saponified. The soaps are dissolved in 150 to 200 c.c. of water and decomposed with hydric chloride. The separated fatty acids are filtered and washed with two litres of boiling water, and dried at 95° to 98°C.; they are then weighed.

If the fixed fatty acids are over 90 per cent., there is admixture of foreign fat in the butter.[1]

Artificial Butter—Margarine

Oleo-margarine was first manufactured by a process discovered by Mége-Mouriès.[2] Several products have since that time been sold under the name of *butterine*; all such products are now by law (1887) directed to be called *margarine*. Oleo-margarine is chiefly made from beef fat, from which most of the stearin is removed; the product is mixed with milk, and colouring and flavouring compounds. Other 'margarines' are made from beef fat, olive oil, and milk, and others from tallow, lard, rapeseed oil, and palm oil.[3]

They have not the characteristic smell of butter either when fresh or when saponified. The fixed fatty acids obtainable from them are from 92 to 95 per cent. The average melting point is 28° C. to 31° C., and the average composition is 8 to 15 per cent. of water, 80 to 92·5 per cent. of fat, and 5 to 6 per cent. of casein, colouring matter, and salts.

As an an article of food, margarine supplies to the poorer clases a cheaper fat than butter, and, although not so assimilable, it is yet of great nutritive value.

Cheese

Cheese is an important product of milk. It is made from milk simply, or milk to which cream is added, or from milk with the cream for the most part removed. Different kinds of cheese thus vary in composition, chiefly, however, in the amount of fat they contain. They all contain casein, fat, lactose, salts (with in some cases added sodium chloride), and water; but the organic foodstuffs have during the ripening of cheese undergone decomposition, chiefly the fat and casein, and to some extent the lactose; so that cheese contains free fatty acids, butyric, lactic, and some of the higher fatty acids. Considered as a food, the smaller amount of free acids the cheese contains, the better is it. It also contains leucin, tyrosin, and ammonium salts. They react either alkaline or acid to test paper. As an *article of diet* cheese is very useful, since it contains a large quantity of proteid or fat in a concentrated form. But this concentration is from the point of view of digestibility a great drawback, since the harder the cheese is, the more difficult of digestion is it, and remaining a long time in the stomach it sets up and aggravates the symptoms of fermentative or acid dyspepsia. Some people, too, even with healthy digestions, cannot eat cheese; and this, taken with the general indigestibility of the substance, makes the nutritive value of cheese much smaller than would appear from its composition, and from experiments with artificial digestion.[4]

Composition of Cheese.—This varies according to the milk from which

[1] For Reichart's method, which is an estimation (in terms of alkalinity) of the volatile fatty acids obtainable from butter, see *Zeits. Anal. Chem.* 1879, p. 68, or Hilger, *op. cit.*

[2] See Boudet, *Rapp. fait au Conseil d'Hygiène*, etc., *autoris. la Vente de la Margarine Mouriès.* Paris, 1872.

[3] Cf. Hilger, *op. cit.*

[4] For an account of these see König, *op. cit.* p. 382.

the cheese is made, and according to the length of time during which the cheese 'ripens.'

Cream cheese is made from cream or cream and milk. In it, therefore, the fat is in greater proportion than the casein.

'*Fatty cheese*' is made from milk simply.

'*Half-fatty cheese*' is made from equal parts of skimmed milk (evening milk allowed to stand twelve hours) and of morning milk. In it the fat is about equal to the casein.

'*Lean cheese*'[1] is made from skimmed milk or partially skimmed milk. The fat in it is much less than the casein.

Percentage Composition of Cheeses

—	Water	Casein	Fat	Lactose, &c.	Salts	Sodium chloride added
1. *Cream cheese*	30·66	2·84	62·99	2·03	1·15	—
2. *Fatty cheese* (such as Stilton,[2] Cheddar, Gloucester, Gorgonzola, Roquefort)	38·0	25·35	30·25	1·43	4·97	2·37
3. *Half-fatty cheese* (Gruyère, Dutch)	39·79	29·67	23·92	1·79	4·73	1·97
4. *Lean cheese* (such as Parmesan)	31·80	41·19	19·52	1·18	6·31	—

Compared to medium fat beef, a fatty cheese contains 1·2 time more proteid and 5·6 times more fat.

Bad Effects of Cheese.—Besides the effect on digestion above mentioned, cheese, when it has become sour, may cause diarrhœa. The ptomaine, tyrotoxicon, may also be developed and cause symptoms of poisoning.

Adulterations.—Starch is the commonest addition to give weight. It is detected by the blue colour given with iodine. The fat may also be removed with ether, so that the residue is easily examined microscopically for starch grains and coarse additions.

Small quantities of copper, zinc, and lead may be found in the ash. Arsenious acid may be found in the rind.

Cheese often becomes green and red, owing to the development of fungi; and an acarus (cheese-mite) commonly is found in old cheese. When mouldy, cheese contains in large quantity the products of decomposition by bacteria.

EGGS

Hens' eggs are the usual form in which eggs are eaten as food, but ducks' eggs are also used, and on the sea-coast the eggs of sea-fowl.

Composition.—Hens' eggs vary greatly in size and in weight. Thus small eggs weigh between 45 and 50 grammes, the medium-sized between 55 and 60 grammes, and the large ones 70 grammes or over (Förster). The average weight is about 58 grammes (two ounces).

The shell forms 10 per cent. of the weight; it is relatively greater in the smaller eggs than in the larger. The egg itself consists of two parts—the white and the yolk in the proportion of 67 to 33. The white contains chiefly albumin (egg-albumin), with a trace of fat and a small proportion of salts; the yolk contains a globulin (vitellin) and a large quantity of fat and a larger proportion of salts than the white.

[1] The German terms 'Fettkäse,' 'Halbfetterkäse,' 'Magerkäse,' have been literally translated to express these different kinds of cheese.

[2] Stilton is sometimes considered as a cream cheese, but in composition it belongs to Class 2.

Composition of the Hen's Egg (König)

—	Water	Proteid	Fat	Free extractions	Salts
Whole egg (less shell) .	73·67	12·55	12·11	0·55	1·12
White of egg . . .	85·5	12·87	0·25	0·77	0·61
Yolk of egg . . .	51·03	16·12	31·39	0·48	1·01

The yolk of ducks' eggs contains more fat than that of hens' eggs. The fatty bodies of the yolk consist of the neutral fats—palmitin and olein, cholesterin and lecithin. A small quantity of grape-sugar is also found, and the most important mineral constituent present in the yolk is iron united with an organic body. Potassium and phosphates are in excess in the salts over sodium and chlorides. In the white, the sodium and chlorides are in excess.

Ptomaines have been found in eggs (Gautier) and albumoses, but only in very small quantities; the presence of both these classes of bodies is to be ascribed to incipient decomposition.

Digestibility of Eggs

According to Rubner, with an egg diet most of the proteids are absorbed, only about 3 per cent. of nitrogen being found in the fæces (equal to about 20 per cent. proteid), while the fat is not so well absorbed, about 5 per cent. appearing in the fæces. Eggs disagree with some people, and when incipient decomposition is established ought not to be eaten.

Preservation of Eggs

Eggs are preserved by excluding air from entering through the shell. This may be done by covering the shell with oil or gum, or with insoluble lime compounds. Good eggs sink in a 10 per cent. solution of common salt: bad ones float.

FLESH

The muscular tissue of various animals—chiefly herbivorous—and of fish and of birds, forms one of the chief foods of adult man. Not only, however, is the muscular tissue utilised, but also some of the internal organs, and some invertebrate animals are also eaten. These will all be considered under the heading of FLESH.

MEAT

The flesh of many animals is eaten by man in different parts of the world: but that chiefly used is obtained from the ox (beef), the calf (veal), the sheep (mutton), the pig (pork), and the goat. The flesh of wild animals (deer, &c.) is also eaten, but it is in civilised countries a luxury, and does not enter into the dietary of the majority.

Composition

Flesh in the form of meat is a food containing many substances. It is chiefly utilised as a *proteid*, a *fatty*, or a *saline* food, the carbohydrate constituents being in very small quantity. The chief *proteid* is myosin, which exists in the muscle-fibre itself, and constitutes the greater part of the amount of nitrogenous element mentioned in the table. It is a globulin, soluble only in saline solutions, and in dilute acids and alkalies, and is coagulated by a heat below 100° C. These properties show why it is not present in solution in ordinary beef-tea. Myosin itself is the result of coagulation of the living muscle which occurs on its death—that is, on the onset of rigor mortis. The

meat is in this state hard. When the rigor mortis passes off the meat becomes tender and is fit for cooking.

Other proteids present in meat are a small quantity of alkali-albumin,[1] serum-albumin, and globulin derived from the blood; *gelatin* formed in the process of cooking from the connective tissue surrounding the fibres, the vessels, and nerves, and a small quantity of *elastin*. The next most important dietetic constituent of meat is the *fat*. This exists attached to the muscles (part of the subcutaneous fat), but in well-fed and in fattened animals it is found in the connective tissue between the muscle fibres; meat may thus be spoken of as fat, medium fat, and lean, and these three kinds have necessarily a different dietetic value in considering a given dietary. The amount of fat in the meat varies in different kinds of beef, in mutton, and especially in pork, which is thus rendered indigestible. The flesh of young animals (calf and lamb) is lean meat.

The fat itself solidifies after death and is composed of stearin, palmitin, and olein in different proportions, the more solid fats containing an excess of stearin (see p. 395).

The *saline constituents* of meat consist mainly of potassium and phosphoric acid; magnesium is in greater abundance than calcium. Sodium and chlorine are in less quantity. This follows the general rule that the liquids of the body contain sodium and chlorine in excess of potassium and phosphate, while in the solid parts of the tissues the reverse holds good. In 1,000 parts of the ash, there are 4·654 parts of K_2O, 0·770 of Na_2O, 0·086 of CaO, 0·412 of MgO, 0·057 of Fe_2O_3, 4·644 of P_2O_5, 0·672 of Cl, and a trace of SO_2.

Glycogen is the chief carbohydrate in meat; it forms usually only 0·5 per cent. After death it is mostly changed into grape-sugar. *Inosit* (muscle sugar) is isomeric with grape-sugar; it occurs in very small quantity. The so-called *extractives* of meat are important, since they constitute the stimulating principles of beef-tea and other broths. These are mostly nitrogenous crystalline bodies derived from the proteid metabolism of the muscle; creatine and creatinine are the chief, but taurin, sarkine, xanthine, carnine, urea, and uric acid also occur to a less extent.

Sarcolactic acid is a product of the activity of muscles; it is formed to a great extent during rigor mortis.

—	Water	Nitrogenous substances	Fat	N.-free extractives	Ash	Proportion of nit. to non-nit. foodstuffs
Beef (very fat)	53·05	16·75	29·28	—	0·92	—
„ (medium fat)	72·03	20·96	5·41	0·46	1·14	1 : 0·28
„ (lean)	76·37	20·71	1·74	—	1·18	—
Veal (fat)	72·31	18·88	7·41	0·07	1·33	—
„ (lean)	78·84	19·86	0·82	—	0·50	1 : 0·04
Mutton (very fat)	53·31	16·62	28·61	0·54	0·93	—
„ (medium fat)	75·99	17·11	5·77	—	1·33	1 : 0·33
Pork (fat)	47·40	14·54	37·34	—	0·72	1 : 2·57
„ (lean)	72·57	20·25	6·81	—	1·10	1 : 0·33
Horseflesh	74·27	21·71	2·55	0·46	1·01	1 : 0·14
Internal organs:						
Tongue and heart	65·66	19·61	13·75	0·10	0·88	1 : 0·7
Kidney[2]	76·58	16·64	5·56	0·10	1·12	1 : 0·34
Liver	71·39	19·72	5·55	1·69	1·65	1 : 0·36

The preceding table gives the percentage composition of different kinds of meats (König).

[1] This alkali-albumin is formed from the globulin of muscle when the tissue is alkaline.

[2] Average of ox, sheep, and pig's kidney.

Meat is chiefly a proteid and fatty food. It is not to be deduced that the amount of nitrogenous substances given in the above table is completely available for assimilation. In other words, the 21 per cent. of nitrogenous substances in beef does not consist solely of myosin and serum albumin, which are of great nutritive value, but also of gelatin and elastin, the nutritive values of which are not equal to that of myosin; and of the nitrogenous extractives, which are stimulants and are not proteid foods. Parkes gives the total proteids of beef and mutton as 17 per cent., of which 13 per cent. are useful, i.e. assimilable by the organism. Rubner, however, found that only 2·5 per cent. of the nitrogen taken in as proteid of meat was passed out in the fæces. This reckons the percentage of proteids in meat as 20·96, of which, therefore, 18·46 per cent. are available for the organism—a higher reckoning than that given by Parkes. These experiments were done with good meat. Meat as sold, however, contains gristle and bone, and Parkes's figures may be taken as accurate for the proteid value of meat inclusive of gristle but exclusive of bone.

Bone forms about 20–25 per cent. of the meat as sold. It is relatively more in young animals; in veal, for example, it forms as much as 30 per cent. and over (Förster). Fattened and well-fed animals also possess relatively less bone than the badly nourished. A well-nourished lamb has 5½ per cent. of bone, a similar animal poorly fed over 8 per cent. of the weight during life (Weiske). This proportion of bone is thus important, as the meat (inclusive of bone) obtainable from differently nourished animals varies.

In thin oxen . . .	53–60 per cent. of the life-weight is meat with bone				
In medium-fed . .	55–65	,,	,,	,,	,,
In well-fed . . .	60–70	,,	,,	,,	,,
In fattened pigs . .	80–85 [1]	,,	,,	,,	,,

A full-grown sheep weighs 60–90 lb. or more, and yields 60 per cent. of available food; a full-grown pig weighs 100–180 lb. or more, and yields 75–80 per cent. of available food.

The amount of *fat* in meat varies with the feeding of the animals. In a fat ox it forms about one-third of the flesh, in a fattened pig about one-half (Lawes and Gilbert). In thin and badly nourished animals, on the other hand, the amount of fat may be reduced to 1·3 per cent of the meat, or even lower (Siegert).

The fat of animals when separated varies slightly in composition in the different animals.

Composition of Animal Fats (percentage)

—	Water	Membrane	Fat	Proteid	Salts
Mutton and beef suet .	10·22	1·40	88·38	—	—
Pig's fat	6·44	1·35	92·21	—	—
Lard	0·70	—	99·04	0·26	Traces
Beef tallow	1·33	—	98·15	0·44	0·08

Artificial butter (margarine) is made from animal fats (see p. 439).

Variations in the Composition of Meat

These have been partly discussed above. The amount of bone varies, but the greatest difference between meat from different animals is in the amount of fat present. The flesh of young animals and of fish contains more gelatin (when cooked) and less proteid than that of adult animals.

[1] Förster, *op. cit.* p. 165.

Digestibility of Meat—Cooking

Both the preparation and the digestibility of meat have already been discussed (p. 422); also the preparation of soups, broths, &c.

Fish

Many varieties of fish are eaten as food; both fresh and in the dried or 'cured' state. As food, however, fish may be considered as divided into two classes, the fatty and the non-fatty. Of the fatty, the salmon, herring, and mackerel may be quoted as examples; and of the non-fatty, the cod.

Percentage Composition of the Flesh of Fish

—	Water	Proteid	Fat	Salts	Sodium chloride	Proportion of nit. to non-nit. foodstuffs
Fat Fish:						
Salmon (*Salmo salar*) . . .	64·29	21·60	12·72	1·39	—	1 : 0·59
Herring (*Clupea harengus*) . .	74·64	14·65	9·03	1·78	—	1 : 0·61
Mackerel (*Scomber scombrus*) .	71·20	19·36	8·08	1·36	—	1 : 0·41
Lean Fish:						
Cod (*Gadus morrhua*, var. *G. calarias*)	82·20	16·23	0·33	1·36	—	1 : 0·02
Cured Fish:						
Dried cod (unsalted) . . .	16·16	81·54	0·74	1·56	—	—
„ (salted)	13·20	73·72	3·37	9·92	4·74	—

Fish are preserved by smoking and salting.

Diseases Caused by Meat

Meat forming such a large proportion of the diet of man, it is evident that a proper inspection of the meat sold with the view of the rejection of not only unwholesome meat, but also of doubtful kinds, is extremely important to the health of the community. (See article on Meat Inspection.)

1. Meat may undergo changes (putrefaction) after being prepared for the market. It seems doubtful whether meat, healthy when prepared, can communicate acute infective diseases, after being exposed to contagion; but meat, especially pork and ham, has been shown to be affected by micro-organisms, which produce a specific diarrhœal disease in man (p. 445).

2. It may also be affected by drugs which have been administered to the animal, or by the peculiarity of its fodder.

3. It may be affected by disease of the cow; and the proper investigation of these kinds of diseased meat is of the highest importance.

1. *Putrefactive Changes of Meat.*—Healthy beef has a marbled appearance, is of reddish colour, firm consistence, and gives a reddish juice on allowing it to stand some time. The fat is firm, whitish yellow in colour, and does not show any hæmorrhagic spots.

In putrefaction the meat becomes of a less firm consistence, paler in colour, and finally emits an offensive odour. The colour finally changes to a greenish yellow, and parts of the meat are easily torn or become diffluent; a knife thrust into such meat smells offensively on being withdrawn; the marrow soon decomposes and becomes diffluent and offensive. The changes are due to the action of putrefactive bacteria, feeding on the proteid bodies which are broken up with the production of, in many cases, crystalline products—the so-called cadaveric alkaloids or ptomaines.[1]

[1] L. Brieger, '*Ueber Ptomaine*,' parts i. and ii. 1885; part iii. 1886.

From meat (beef and horseflesh) which has been allowed to decompose in water at the temperature of the blood for five to six days, Brieger has separated several alkaloids, neuridine, neurine, choline, and, most important of all, an alkaloid apparently identical with muscarine, the active principle of *Amanita muscaria* (Schmiedeberg and Koppe). This alkaloid produces the following symptoms in animals: first, a great increase in the secretions—salivation, nasal discharge, lachrymation, sweating, and diarrhœa—the respiration is also quickened, becoming finally dyspnœic, and with a large dose asphyxial clonic spasms may be noticed. The cardiac beat is accelerated, the blood-pressure sinks, and the heart finally stops in diastole. Similar 'muscarine-like' symptoms are produced by neurine and choline, although large doses require to be administered. From decomposing horseflesh Brieger separated a poison acting like curare—viz. paralysing the ends of the motor nerves. From decomposing fish, Brieger has separated several alkaloids—trimethylamine, methylamine, diethylamine, neuridine, cadaverine, putrescine. Cadaverine and putrescine do not appear very poisonous unless injected into the circulation, in which case they produce 'hæmorrhages and ulcerations' very similar to those occurring in cholera.[1] They do not, however, cause muscular cramps. There are probably other poisons in decomposing flesh, not yet separated. It is important to notice that Brieger found the poisonous effects of neurine, choline, and of muscarine (from decomposed meat) neutralised by the administration of atropine.

The flesh of some animals which is not decomposed may be poisonous: the common mussel, the sea-water mussel (*Mytilus edulis*) and some crustacea are sometimes poisonous. No definite poison has been separated from such animals, with the exception of the sea-water mussel. In the outbreak of mussel-poisoning occurring at Wilhelmshaven in Germany, the mussels were found to contain a poisonous alkaloid—mytilotoxine—which produced the symptoms of poisoning noticed in the persons who were affected.

The *symptoms in man* produced by the consumption of decomposed flesh are chiefly confined to the gastro-intestinal tract, as shown in nausea, vomiting, abdominal pain, and diarrhœa, sometimes choleraic in character. With these signs, there is prostration and sometimes a rash on the skin of an urticarial or erythematous character. Symptoms, however, may be altogther absent.

In a fatal outbreak of diarrhœa occcuring at Welbeck in 1880, Dr. Ballard showed that the eating of ham was the cause, and (with Dr. Klein) demonstrated that the disease was due to a specific bacillus. This micro-organism also appeared to account for a similar outbreak of diarrhœa at Nottingham in 1881, which was also investigated by Dr. Ballard.[2]

2. The peculiarity of the fodder may impart a disagreeable smell to the meat, but actual poisonous properties transmitted from the fodder to the flesh is more often observed in birds feeding on certain berries. Beef may become poisonous by the cattle feeding on poisonous plants, delirium and the symptoms of narcotic poisoning being observed when the meat is eaten by man.

Similarly the meat of cattle which have been dosed with arsenic and antimony previous to slaughtering may cause poisonous symptoms—vomiting, diarrhœa, &c., when eaten, owing to the presence of the metal in the meat.

3. The most important question in regard to the deleteriousness of meat is how far it is affected by disease of the animal. It is still doubtful to what

[1] See Brieger, *op. cit.* Udranszky and Baumann, *Zeits. f. Physiol. Chemie*, xiii. 562. For further information on ptomaines see Selmi, *Sulla Ptomaine*, &c. Bologna, 1878; *ibid.* 1882. Guareschi et Mosso, *Les Ptomaïnes*, Turin, 1883. Gautier, *Sur les Alcaloïdes dérivés de la destruction bactérienne*, &c. Paris, 1886.

[2] See *Report* of Medical Officer of Local Government Board, 1880.

extent the diseases of the animals used by civilised man affect the meat so as to render it unfit for consumption. Some facts are, however, definite, and will now be discussed.

Disease of the animal may affect the meat in two ways :—

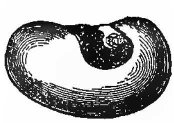
1. The meat may be infected with the young of worms.

2. It may be altered in composition by the general or local disease of the animal, so as either to diminish the nutritive value of the meat or to render it actually injurious.

Parasites (*Animal*)

a. The *pig* is infested with two parasites which are of importance to man; both these have their habitat in the flesh (pork): the one, *Cysticercus cellulosæ*, gives rise to the common tape-worm (*Tænia solium*) in man, the other, *Trichina spiralis*, gives rise to a disease in man, trichiniasis, which is often fatal.

Cysticercus cellulosæ may be detected during life by examining the under surface of the tongue; if necessary, one of the vesicles may be removed for microscopic examination. The parasite renders the flesh 'measly,' i.e. the meat has scattered through its substance small, round, whitish yellow bodies.



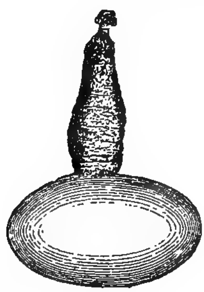


FIG. 90. FIG. 91.
Cysticercus cellulosæ, with head retracted (fig. 90), and extruded (fig. 91). (Leuckart.)

A microscopical examination ought, however, to be made. By digesting the meat with pepsin and hydrochloric acid for some hours at 40° C., the bladders fill to the bottom of the vessel, and may then readily be examined (Schmidt—Mulheim). The bladders vary in size, and are composed of a sac, with liquid contents, in which float calcareous and other particles. At one part the sac is prolonged into a head, which is crowned with hooklets. These hooklets are diagnostic of cysticercus, and are not readily dissolved by liquor potassæ. The pork may therefore be heated for a few minutes with the caustic solution, when the bladders and numerous hooklets will be set free if the treatment be continued.

Cysticerci are killed by a temperature of 57°–60° C. (Lewis), and as the temperature of well-cooked meat is about 65° C. such meat containing cysticerci would be harmless if eaten. But no dependence can be placed on the meat being so well done; therefore, pork containing cysticerci ought always to be condemned as food. Neither salting nor the ordinary smoking kills the cysticerci.

Trichiniasis is a serious result of eating diseased pork when imperfectly cooked, and after being made into sausages. The disease is rare in England, but common in Germany.

Trichinised pork shows small white specks between the bundles of muscle fibres; these are the encapsuled worm (figs. 92 and 93). When eaten, the eggs which are freed in the alimentary canal develop, and the embryos pass through the walls of the gut, and migrate to the muscles and other parts. During this migration they produce trichiniasis, which first appears some time after the ingestion of the meat. Diarrhœa and loss of appetite are often noticed first. Then there is a fever, with severe muscular pains and contractions,

weakness, and even coma. Death may occur within a few weeks. The early symptoms sometimes resemble those of typhoid fever.

Trichinæ, when free, are killed by a temperature of 63°–70° C., the albumen becoming coagulated. Ordinary smoking does not destroy them, nor does decomposition; hot smoking is fatal (Leuckart). Trichinised fish is unfit for food.

b. The cysticercus of beef gives rise to *Tænia mediocanellata* in man, a tape-worm without hooklets, and with four pigmented suckers.

c. In mutton, Cobbold described a cysticercus which was the young of *Tænia tenella*; very little is known about it. The cysticercus has a double crown of hooklets.

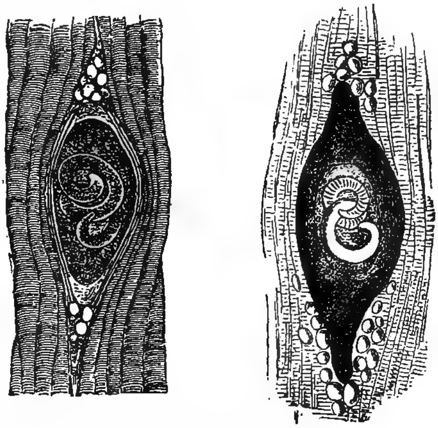


FIG. 92. FIG. 93.
Trichina spiralis in muscle fibre (Leuckart).

Flukes are common parasites in the liver of sheep; they are probably rendered completely innocuous by cooking.

Echinococcus disease affects sheep and cattle in Iceland: it gives rise to hydatid disease in man, the original infection coming from the adult worm (*Tænia echinococcus*), which is found in the dog.

The flesh of domestic animals (beef, mutton, pork) may contain oval bodies from $\frac{1}{300}$ to $\frac{1}{4}$ inch in length, which are called Psorospermia or Rainey's corpuscles. They are probably innocuous to man, but in pigs and sheep may produce symptoms of illness.

Meat of Diseased Animals

There is very little accurate knowledge as to the deleterious or non-deleterious character of the meat of animals affected with general diseases. In some cases such meat has produced serious symptoms; in other cases it is harmless. The symptoms are chiefly those previously described or caused by decomposed meat—viz. sickness and diarrhœa with prostration, and in some cases fever. The poisons in the meat which produce these symptoms are not known, and until further investigation has been made, it is impossible to say whether they are alkaloidal, or whether they are produced from a transformation (non-alkaloidal) of the proteids of the meat.

In many cases of disease the meat is pale and moist, and is altered in consistency. It may also be tasteless.

The meat of cattle suffering from epidemic pleuro-pneumonia is considered by some harmless, and a large quantity of such meat goes into consumption; that of those suffering from foot-and-mouth disease is also probably harmless. Cattle plague is considered in Belgium to affect the meat dangerously; cases, however, where no harm has resulted from the consumption of such meat are recorded. Small-pox in sheep injuriously affects the meat, which ought not to be consumed.

Doubt exists as to the value of the meat of animals suffering from anthrax and erysipelas carbunculosum. The organism in anthrax (*Bacillus anthracis*) is rendered innocuous by exposure to a temperature of 55° C. (Toussaint).

The bacilli would therefore be destroyed in the cooking, and this result would explain the harmless consumption of the meat in many cases. Infection might, however, be produced by handling the uncooked meat if there were an abrasion of the skin. Black-quarter (symptomatic anthrax, erysipelas carbunculosum) may cause the meat to be poisonous (Gamgee).

The question whether tuberculosis can be transmitted to man by meat is an important one, which is not yet decided. It may safely be said, however, that meat which contains tubercles in any stage, and in which tubercle bacilli are found, ought to be condemned as unfit for human food; and in London and three towns in the British Isles lately (1889) this has been the magisterial decision. Tubercles, however, are not commonly found in meat. The only doubtful question is whether cows affected with tuberculosis (*Perlsucht*), but in the meat of which there are no tubercle or tubercle bacilli, ought to be allowed for human food—i.e. in cases where the disease is limited to the internal organs. Such meat is often quite normal in appearance. At present the question cannot be considered as settled.

Preservation of Meat—Preparations

A common mode of preserving meat is by freezing, and in a frozen state it is imported in large quantities from America and Australasia. Other modes are drying, and in some cases powdering (forming the so-called 'meat powders'), and also smoking, during which process the meat becomes partly dried.

The chief defect of the preparations of beef, mutton, and veal is that they are unsavoury, and do not cook well, and cannot for a long time be partaken of with advantage. Such preparations are of chief use for soldiers and sailors in time of war.

Many extracts of meat are now sold, some of which act as stimulants (such as Liebig's Extract), and others are useful, both as stimulants and as nitrogenous foods. The latter may be described as nitrogenous beef-teas.

In time of war, the mixtures of meat with vegetables, in the form of sausages or concentrated soups, have been found of great use; but owing to want of the natural flavouring of the meat, the food soon causes loss of appetite for it. Such preparations are those of mutton and rice, veal and rice, smoked mutton and beans, German pea-sausage (*Erbswurst*) made of pea-flour and fat pork, with many others, chiefly Russian preparations.[1]

The following table gives the composition of some of these preparations of meats:—

Preparations of Meat, with and without added Vegetables (percentage Composition)

—	Water	Proteids	Fat	N.-free extractives	Ash
Carne pura (American dried beef, powdered)	10·99	69·50	5·84	0·42	13·25
Hassall's flour of meat (mixed with 8 per cent. arrowroot, $8\frac{1}{2}$ per cent. sugar, and 3 per cent. salts and pepper, &c.)	12·70	57·00	11·00	15·50	3·80
Tinned meat	55·80	29·04	11·54	—	3·62
German pea-sausage (*Erbswurst*) (average)	6·53	15·46	37·94	31·38	8·69
Ham (Westphalian)	28·11	24·74	36·45	0·16	10·54

Many preparations (chiefly of beef) are now made by partially digesting the meat, and drying more or less completely. The preparation is in some cases mixed with carbohydrates. It will suffice to mention a few of these articles: they are chiefly used for invalids. Darby's Fluid Meat, a liquid preparation,

[1] See König, *op. cit.* i. 232 and 242.

contains 30·70 per cent. of peptone. It has an agreeable odour and aroma. Carnrick's Beef Peptonoids is a dried powdered mixture of digested beef and gluten and concentrated milk. It contains 56·62 per cent. of albumose (propepton), 7·11 per cent. of peptone,[1] with 5·5 per cent. of salts. Kemmerich's Fleischpepton contains 14·56 per cent. of albumose and 32·57 per cent. of peptone, while Koch's somewhat similar preparation contains 15·95 per cent. of albumose and 18·83 per cent. of peptone.

Beef-tea is usually made from the skin or breast of beef, but the best kind is made from beefsteak. In its preparation, the beef must be freed from tendon and any excess of fat, and cut into small pieces. It is then covered with cold water, salt added, and placed on the hob for two to three hours; hot water is added, and the mixture allowed to heat gently from one to one and a half hours, the temperature never being raised to the boiling point. By this means most of the salts and extractives are dissolved out of the meat, together with some gelatine and fat.

Beef-tea is not a proteid food, since it contains only a trace of other proteid besides gelatine; most of the myosin is coagulated during the preparation, and in order to utilise this myosin as food, it is best to take the 'dregs' of the beef-tea as well as the liquid. Beef-tea is a salty food, containing the sodium chloride from the blood and the interstitial liquid of the muscle, and the potassium and phosphates from the muscle fibre itself (see p. 442). It is also a stimulant to the nervous system, and a restorative of muscular energy. These effects are ascribed to the extractives, and chiefly to creatine, which is in larger amount than the other extractives. The mineral salts, however, may participate in this stimulant effect. Soups made without the addition of vegetables have a composition and action similar to that of beef-tea; if bones are used in their preparation, they contain more gelatine and salts than ordinary beef-tea.

Liebig's Extract of Meat (Extractum Carnis) is prepared by freeing the meat from fat and tendon, and applying a moderate heat; the juice exuding is the extract. Sufficient heat is not employed to change the collagen into gelatine, so that the extract consists almost solely of salts and extractives, creatin, and the other nitrogenous non-proteid bodies present in muscle. Liebig's Extract is thus not a proteid food, but is a salty food, and a powerful stimulant like beef-tea. It is a useful agent to restore mental or bodily activity.

Extractum Carnis is also made by pressure alone, without the application of heat. Many other preparations are in the market, concentrated forms of beef-tea. They do not keep like Liebig's Extract, but they are more pleasant to take.

VEGETABLE FOODS

Articles of diet derived from the various parts of plants, seed, stem, root, leaves, &c., have three chief functions to perform. First, they are the chief source (in fact the only practical source) of the carbohydrate food of the animal; for although, as we have seen, glycogen is a constituent of meat and of liver, it is in too small quantity to supply the needs of the economy: therefore it is necessary to consume vegetable starches and sugars. Secondly, they supply a large amount of salts to the body—phosphates, calcium, magnesium, potassium, and iron, while sodium and chlorides are present in deficient quantity, as has already been pointed out. Owing to the amount of water they take up during cooking, they also supply a large quantity of

[1] The analysis was performed before the recent researches of Kühne and Chittenden on albumoses; hence most of this peptone must be considered as albumose. The same remark applies to other analyses of 'peptone' preparations.

water to the organism. Uncooked fruits also perform this function. Thirdly, they are antiscorbutic. This action in this respect varies in the different vegetable foods, and it is not known what particular constituent or constituents possess the effect of preventing and of curing scurvy. This antiscorbutic action is of great importance in considering vegetable foods.

Stress has been laid under the first heading to the fact that vegetable food is the chief source of the carbohydrate ingested. To a less extent they are the source of proteid food. As we shall see, the Leguminosæ are rich in proteids, but, as has already been pointed out, the mixture of proteids, carbohydrates, cellulose, and salts, present in the leguminous foods does not form a combination in which the proteids are most easily assimilable by the organism. The proteids of the cereals, and especially of wheaten flour when made into bread, are not to be forgotten as of great importance.

Vegetable fats are of secondary importance as food. Most of the vegetable foods contain but little fat, and this is not so digestible as animal fat. The fatty vegetable foods (chiefly varieties of oats) are not in general use as foods among civilised races. Olive oil (with its common adulteration, cotton-seed oil) does not form an important constituent of dietaries. The fat of diets is usually derived from animals—butter, &c.

Preparation of Vegetable Food.—The seeds of the cereals, and of some of the Leguminosæ after removing the outer coats, are ground into flours. The advantages of this mode of preparation are plain. It removes a large quantity of cellulose, which is not only indigestible, but prevents the complete digestion and absorption of the foodstuffs, and it renders the food-article more easily cooked and digested, owing to the fine division and the ease with which the starch grains are acted upon by boiling water (see pp. 418 *et seq.* for cooking and digestibility of vegetable foods). During the process of milling there is a slight loss in the percentage of proteid, and a greater loss of salts with a corresponding increase in the percentage of carbohydrates (see tables following). In the case of wheaten flour, the better the milling, the less cellulose there is present, and the less salts, while the whiteness of the flour increases, although the colour to some extent depends on the natural colour of the varieties of wheat.

Wheaten flour undergoes a further preparation into bread; rye flour is also made into bread; millet and buckwheat yield an inferior kind of 'bread.'

General Composition of Vegetable Foods; Characters of the Foodstuffs

1. *Proteids.*—The characters of the vegetable proteids have already been partly discussed. The researches of Vines, the author, and others of late years have tended to show that in the seeds of plants the two chief proteids present are of the nature of a globulin and of albumoses. The legumin and conglutin of leguminous seeds, Vines considers, are artificial products of the action on the globulin of the dilute potash solution used in extracting. This point is, however, not quite settled. Some of the vegetable proteids exist in a crystalline form; a crystalline form of vegetable vitellin has been described by Maschka,[1] Weyl, Schmiedeberg,[2] and others. The aleurone grains found in the cells of plants consist partly of crystalline proteids (Vines). It may be pointed out again here that the nutritive value of the proteids of leguminous seeds is probably equal to that of animal proteids (in meat, eggs, &c.), as the experiments of Rutgers (previously quoted) and others have

[1] *Journ. prakt. Chem.* Bd. lxxiv. p. 436.

[2] *Zeit. für physiol. Chemie,* Bd. i. p. 205. See also *Journ. prakt. Chem.* Bd. cxxxi. pp. 105, 481.

shown; but that the admixture with other foodstuffs and with cellulose found in the seeds renders them less serviceable as proteid foods than meat from animals.

The most important vegetable proteid is the gluten of wheat, owing to the fact that bread is a universal article of diet and a necessity of ordinary life. Gluten is not present in wheaten flour, but is formed from the globulin and albumose present by the action of water.[1] It is composed of gluten fibrin, derived from the globulin, and of insoluble albumose, derived from the soluble form in the flour. This insoluble albumose probably corresponds to Ritthausen's gluten-casein: the occurrence of this observer's gliadin and mucedin was not confirmed by the author. Some of the reactions of gluten are important from a dietetic point of view. Boiling water, for example, coagulates the gluten-fibrin and dissolves out part of the albumose; while uncoagulated gluten is completely soluble in dilute acids and alkalies, although with some difficulty. This solubility, with its ready digestibility by pepsin-hydrochloric acid and by pancreatic juice, renders gluten a valuable proteid food. Rye flour yields a gluten with water, but to a less extent than wheaten flour, and it cannot be obtained readily by washing, like wheat-gluten.

2. *Fats.*—The fats of the vegetable foods in ordinary use are quite unimportant from a nutritive point of view, being present in small, and even minute quantity.

3. *Carbohydrates.*—Starches, dextrines (gums), and sugars are found in vegetable foods. In the seeds of cereals and Leguminosæ the starch is the chief carbohydrate, although dextrines and sugars are also present. In some vegetable foods, sugar in the form of cane-sugar (sugar-cane, beet) or in the form of glucose (various ripe fruits) is the only carbohydrate present in quantity. Dextrine is usually present in small quantity with the starch (see special section). The starches vary greatly in physical characteristics, in the size, form, and structure of the starch grain.

Commercial Starches.—The average percentage composition of the starches found in commerce is 16·04 of water, 1·18 of proteid, 0·06 of fat, 82·13 of carbohydrate, 0·13 of cellulose, and 0·36 of salts. Of such an average composition are arrowroot, tapioca, sago, potato starch, and maize starch.

Arrowroot is obtained from different sources. The West Indian is obtained from *Maranta arundinacea*, and is white and granulated in lumps. Forms of arrowroot are also obtained from *Curcuma, Jatropha Manihot* (Rio arrowroot, yielding tapioca), the arum (Portland sago), and *Canna edulis* (Tous-les-mois). All these preparations of starch readily form a clear jelly on cooling after heating with water.

The chief adulteration of true arrowroot (Maranta and Tous-les-mois) is with potato, sago, and tapioca.

Tapioca is made from the pith of *Jatropha Manihot* (the cassava). It is adulterated with potato starch, and sago.

Sago is obtained from the interior of the sago-palm (*Sagus farinifera*). The commercial varieties are 'common' or 'pearl.' The starch is soluble in cold and hot water.

Potato starch is the usual adulteration.

Identification of the Starches by the Microscope

Adulterations of the starches by other varieties is detected best by the microscope. Owing to the characteristic form of the starch granules in such

[1] Weyl and Bischoff, *Ber. d. deutsch. Chem. Gesellsch.* Bd. xiii. 1880, p. 367; Sidney Martin, *Brit. Med. Journal*, II. 1886.

varieties, the adulteration of the pure starches just discussed or of the different flours may be detected. Wheaten flour, being the most important, is the flour usually adulterated.

The structure of the starch grain has already been described (p. 422). Each grain is laminated to a greater or less extent, and has a point round which the laminæ are ranged; this point, which is variously shaped, is the hilum. The lamination, the position of the hilum, the shape of the grain, the character of the contour, and the size all serve in the identification of the varieties.

Starch grains may be divided into two groups: (1) a group in which the contour is even, containing potato starch, most of the varieties of arrowroot, bean, pea, wheat, barley, and rye starch; (2) a group in which the contour is facetted either partially, as in sago and tapioca, or completely, as in rice, maize, and oats.

1. *Starch Grains with even Contour.*—(*a*) *Potato starch* may be taken as the type. The largest grains average 0·0652 millimetre in the longest diameter; the smaller grains 0·024 millimetre.[1] The grains are pyriform in shape, with an eccentric hilum (at the small end of the grain), and the lamination is well marked (see fig. 94).[2]

(*b*) *Bermuda Arrowroot.*—Large grains, 0·044 millimetre; medium-sized grains, 0·02 millimetre; and smallest grains, 0·012 millimetre in the longest diameter.

Fig. 94.—Potato starch.

Fig. 95.—Bermuda arrowroot starch.

Fig. 96.—St. Vincent arrowroot starch.

The grains are ovoid, with the hilum at the larger end, the hilum being a dot, a slit, or crucial (see fig. 95). The lamination is well marked. The grain is frequently beaked.

St. Vincent Arrowroot.—Large grains, 0·0456 millimetre; medium-sized, 0·028; and smallest, 0·012. The grains have the same character as those of Bermuda arrowroot, and it is almost impossible to distinguish them (see fig. 96).

Tous-les-Mois arrowroot has grains like potato starch, but they are much larger. The hilum at the smaller end of the grain distinguishes tous-les-mois from Bermuda and St. Vincent arrowroot.

Curcuma arrowroot has large oblong grains, well laminated; the hilum is at the smaller end of the grain.

(*c*) The grains of *beans* and *peas* are oval or reniform, with a longitudinal hilum, which is irregular in bean starch, but more regular in pea starch. Lamination is indistinct.

Pea-starch grains (*Pisum sativum*), largest grains, 0·044 millimetre in longest diameter; medium-sized grains, 0·028 millimetre; and smallest, 0·01 millimetre (fig. 97).

[1] These measurements are the average of 5 to 10 grains; they give a good idea of the difference of size of grains in the different starches. The measurements are in all cases of the longest diameter.

[2] All the figures are drawn under the magnifying power of Hartnack, Oc. 7, Obj. 3.

Bean-starch grains (haricot bean, *Phaseolus vulgaris*). Average longest diameter, 0·044 millimetre (fig. 98).

(*d*) The starch grains of *wheat* and *barley* cannot be distinguished under the microscope; barley, however, contains many medium-sized grains, while wheat contains only large and very small grains (see figs. 99 and 100).

FIG. 97.—Pea starch.

FIG. 98.—Bean starch (*Phaseolus vulgaris*).

The grains are round and oval, with a central hilum, slit-like, and sometimes star-shaped in the wheat (see fig. 100). Lamination is very faint.

Wheat Starch Grains.—Largest, 0·032 millimetre in longest diameter; smallest, 0·004 to 0·008 millimetre.

FIG. 99.—Barley starch.

FIG. 100.—Wheat starch.

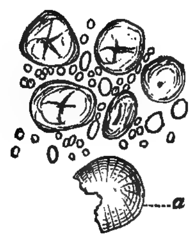


FIG. 101.—Rye starch. *a*, crushed grain.

Barley Starch-Grains.—Largest, 0·03 millimetre; medium-sized, 0·02; smallest, 0·004 to 0·008 millimetre in longest diameter.

The starch grains of *rye* are very similar to those of wheat and barley; the contour is, however, spherical, and the hilum frequently star-shaped (see fig. 101), especially in the largest grains. The smallest grains are 0·004 millimetre in diameter. The medium-sized are 0·02 millimetre, and the largest, 0·04 millimetre in diameter. The presence of these large grains with

FIG. 102.—Sago starch.

FIG. 103.—Tapioca starch.

star-shaped hilus distinguishes rye from barley; the presence of numerous medium-sized grains and of many grains with star-shaped hilus distinguishes rye from wheat.

2. *Starch Grains with a facetted Contour.*—In *sago* and *tapioca*, the grains are partially facetted (see figs. 102 and 103). The grains of sago are large, the

hilum often cavernous, and there is a hollow in the centre of the grain. Lamination is imperfect and irregular. Size of largest grains, 0·059 millimetre; medium-sized, 0·032 millimetre in the longest diameter.

Tapioca is only to be distinguished from sago by the size of the starch grains; these are about one-third the size of the largest grains of sago, i.e. about 0·022 millimetre in the longest diameter (fig. 103).

The starch grains of maize, oats, and rice are completely facetted, and are readily distinguished under the microscope. The points they have in common are that they are completely facetted, and that lamination is very indistinct or absent. In *maize* the facets are the most perfect, the grain being like a disc or half a tetrahedron; the hilum is distinct, stellate, sometimes a mere dot, sometimes cavernous (see fig. 104). The diameter of the grains averages 0·023 millimetre.

In rice (fig. 105) and oats the grains are very small, in the former 0·006 millimetre in diameter, in the latter twice the size, viz. 0·012 millimetre.

FIG. 104.—Maize starch (Indian corn).

FIG. 105.—Rice starch.

FIG. 106.—Oat starch.

Apart from the size, oat-starch grains are readily distinguished from rice by their aggregation into spherical clumps (see fig. 106). They are both distinguished from maize by the size of the grain, and by the fact that in very few grains of oat and rice starch can a hilum be seen.

Sugars.—The two chief varieties of sugar found in commerce are cane-sugar from the sugar-cane (*Saccharum officinarum*), and beet-sugar from *Beta vulgaris*.

White cane-sugar contains, in 100 parts, 93·33 parts of saccharose, 1·78 of dextrose, 0·35 of proteid, 0·30 of gum and vegetable acids, 0·91 of extractives, 0·76 of salts, and 2·16 of water.

Beet-sugar contains, in 100 parts, 94·42 parts of saccharose, 0·21 of invert-sugar, 3·44 of various substances, and 1·93 of water.

The colour of brown sugar is due to invert-sugar, of which there is 4–5 per cent. present. Brown sugar also contains more water than white; on the average 4–6 per cent. is present, but as much as 10 per cent. may be found in coarse brown sugar.

Honey differs from ordinary sugar in containing more invert-sugar (dextrose and lævulose) than saccharose. The composition varies greatly, but on an average, in 100 parts, there are 72·88 parts of invert-sugar (consisting of 38·65 lacculose and 34·48 dextrose), 1·76 of saccharose, 0·22 of dextrine, 0·71 of wax, 0·76 of proteid, 2·82 of non-saccharine substances, 0·25 of ash, 0·028 of phosphoric acid, and 20·60 parts of water. The total invert-sugar may be as low as 64·10 per cent., and as high as 79·37 per cent. Lævulose is, however, always in greater proportion than dextrose.

Honey is adulterated with cane-sugar, with sugar made from starch, and with inert matter.

Salts.—These will be considered under the special headings of foods. As has already been pointed out, potassium and phosphates are in excess

over sodium and chlorides, showing the necessity of common salt to vegetable feeders. Iron is an important constituent of the salts of vegetable foods; in white wheat, for example, phosphate of iron forms 0·31 per cent. of the ash, while in the Peruvian quinoa seeds it is present in the proportion of 0·75 of the whole seed (quoted by Parkes[1]).

A rough but useful classification of vegetable foods may be made according as the organic foodstuffs or the inorganic are the chief constituents present.

1. In one class, for example, there are the food grains, including the cereals, in which the proteids are present in the proportion of about 10 per cent., while the carbohydrates are from 65 to 70 per cent. These foods are chiefly *carbohydrate foods, to a less extent proteid foods.* Edible chestnuts also belong to this class.

2. In another class the seeds of Leguminosæ are included. In these the proteids are from 20 to 25 per cent. (sometimes over 30 per cent. in Soja beans), while the carbohydrates are from 46 to 59 per cent. This class then includes vegetable products which are eminently *proteid, as well as carbohydrate foods.*

3. A third class contains members, such as the potato, in which the proteid is insignificant in quantity, while the carbohydrates are fairly abundant (20 per cent.) To this class would pre-eminently belong the commercial preparations of starch, such as arrowroot, tapioca, and sago.

4. Some vegetables, as the beet and ripe fruits, are also carbohydrate foods; but they have a more important function than this to perform, viz. that of supplying vegetable acids and salts to the organism. In this way foods, such as cabbage, turnips, carrots, &c., act as *antiscorbutics.*

CLASS I. THE CEREALS

The cereals belong to the first class of vegetable foods, those which are chiefly serviceable as yielding carbohydrates, while to a less extent they are proteid foods.

To the cereals belong wheat, barley, oats, rice, rye, maize, and millet. Buckwheat may also be included. By far the most important of these is wheat, as yielding bread, but in some countries other cereals are also of great importance—in Scotland oats, in India rice and millet, and in the Spanish-speaking countries of America maize-cakes take the place of bread, which is almost unknown.

The preparation which these grains undergo and the effect it has on the percentage composition have already been discussed (p. 450). This effect is evident by referring to the tables following. Bread is made chiefly from wheaten flour, but inferior kinds are also made from rye, millet, and buckwheat.

WHEAT (*Triticum vulgare* et sp. var.)

The wheat grain is surrounded by four coats, the outermost of which is cuticular and hairy; the next coat is composed of rounded cells; the third coat is almost hyaline; and the internal coat is also very thin. The second coat is the only conspicuous one. Within the innermost coat is the wheat

[1] *Hygiene*, p. 286.

grain proper, which contains the starch, fat, proteid, and salts of the flour. In the process of milling the coats are removed as far as possible, being separated as bran; in the so-called wholemeal the whole grain is milled.

Percentage Composition of Cereal Grains and of Flours

—	Water	Proteid	Fat	Carbo-hydrates	Cellulose	Ash	Proportion of nit. to non-nit. foodstuffs
1. WHEAT:							
Grain (average of 948 analyses of all countries)	13·37	12·04	1·85	68·65	2·31	1·78	—
Flour, fine	13·37	10·21	0·94	74·71	0·29	0·48	1 : 7·4
„ coarse	12·81	12·06	1·36	71·83[1]	0·98	0·96	1 : 5·98
„ wholemeal (Atwater)	13·00	11·70	1·70	69·90	1·90	1·80	1 : 6·1
2. BARLEY:							
Grain (shelled, average)	14·05	9·66	1·93	66·99	4·95	2·42	—
Flour	14·83	11·38	1·53	71·22[2]	0·45	0·59	1 : 6·4
3. OATS:							
Grain (shelled)	12·11	10·66	4·99	58·37	10·58	3·29	—
Meal (fine)	9·65	13·44	5·92	67·01[3]	1·86	2·12	1 : 5·4
4. RICE:							
Shelled	12·58	6·73	0·88	78·48[4]	0·51	0·82	1 : 11·8
5. RYE:							
Grain (shelled, average)	13·37	10·81	1·77	70·21	1·78	2·06	—
„ German	13·37	11·52	1·84	68·88	2·45	1·94	—
Flour	13·71	11·57	2·08	69·61[5]	1·59	1·44	1 : 6·2
6. MAIZE (Indian corn):							
Grain (average)	13·35	9·45	4·29	69·33	2·29	1·29	—
Meal	14·21	9·65	3·80	69·55	1·46	1·33	1 : 7·6

(For MILLET and BUCKWHEAT see p. 468.)

Wheaten flour, as just stated, is of two kinds, the one ordinarily used being white, the other, wholemeal, being of a dark colour, owing to the admixture of bran.

In the market there are several varieties, according to the completeness of the milling—separation of the coats and grinding of the grain. The most highly milled flours are the whitest, and contain least bran and least cellulose; as has been pointed out, they lose in the process some proteid and some salts, but this loss is more than compensated for by the fineness of the bread prepared from it. The chief flours in the market are in the order of their excellence (fineness and whiteness), Vienna whites, best whites, best households, second households, and other flours inferior in quality. There are also brown meal and whole meal.

We have already stated that the two proteids present in flour are a globulin and an albumose, and that gluten is formed from these by the action of water. All the globulin and albumose is not transformed into gluten—some remains dissolved in the water with which the flour is washed.[6] For the proportion of gluten see p. 461.

The amount of gluten obtainable is a test of the quality of the flour as regards proteid and its capacity for making bread. In bad wheat (due to bad seasons, &c.) very little gluten may be obtainable from the flour, the

[1] The carbohydrates are composed of starch 66·28 per cent., dextrine 4·09 per cent., and sugar 1·86 per cent.

[2] Composed of starch 61·59 per cent., dextrine 6·52, and sugar 3·11 per cent.

[3] Starch 59·39 per cent., dextrine 3·08 per cent., sugar 2·26 per cent.

[4] A small proportion of dextrine and a trace of sugar (Pillitz).

[5] Starch 58·61 per cent., dextrine 7·16 per cent., sugar 3·89 per cent.

[6] This is often erroneously referred to as 'albumen' in works on food, and gluten is spoken of as a constituent of flour.

proteids being in the form of 'soluble albuminoids,' as they are often called, and thus remain dissolved in the water used in washing the flour without yielding gluten. The better the flour the less the 'soluble albuminoids' yielded by water (see EXAMINATION OF FLOUR, p. 461). Why they should not form gluten is not known, any more than why barley, which, according to my researches, contains proteids of the same character as wheat, should not yield gluten at all. Some wheats (called hard) yield much gluten; from such macaroni is made. Soft wheats contain less gluten than the hard, and more starch. The starch presents the characters previously mentioned (p. 453). Some dextrine and sugar are also present (Table, p. 456). The salts consist chiefly of phosphates and potassium and magnesium.

Percentage Composition of Wheat-grain Ash[1]

—	Lawes and Gilbert	Way and Ogston
Phosphoric acid	49·68	45·01
Phosphate of iron	2·36	0·82
Potash	29·35	31·44
Soda	1·12	2·71
Magnesia	10·70	12·36
Lime	3·40	3·52
Sulphuric acid	—	0·34
Carbonic acid	—	0·02
Chlorine	0·13	0·13
Silica, &c.	2·47	3·67
Total	99·21	100·02

Wheat as a Food.—In fine flour the proportion of nitrogenous to non-nitrogenous organic foodstuffs is as 1 to 7·4; the proteids are therefore deficient. Wheat is therefore chiefly a carbohydrate food, although the proteid constituents are very nutritious. When made into bread it is a food which may be eaten for any length of time, since it never cloys; but, as seen from what has been said, it is deficient in two foodstuffs—fat and common salt. The addition of salt to the bread (in the making) and the eating with butter are two empirical discoveries of mankind which have a very rational basis. 'Brown' bread is made from white flour (often not of the best) mixed with varying proportions of bran. It is far below white bread as a food, owing to the admixture of coarse bran and its aperient action.

Of late years it has been proposed to include the whole of the wheaten grain in the making of bread, wholemeal yielding wholemeal bread. The advantages claimed for this process are that the bread is thereby rendered more nutritious; there are more proteid foodstuffs and more salts in the bread. The exact gain depends, of course, on the quality of the wheat originally used. If we take bran as forming 16 parts of the grain, we have an addition of, on the average, 0·7 per cent. of proteid, and 0·16 per cent. of salts. The disadvantages of wholemeal bread are first its dark colour, and the fact that the gain in proteid and salts is accompanied by an admixture of cellulose. This indigestible cellulose, whether the flour is finely milled or not, is not only an irritant to the intestines (as shown by its stimulating peristalsis), and especially so in disease of the alimentary tract, but it also diminishes the absorption of the digestible foodstuffs; a fact which has already been insisted upon. These effects of cellulose more than counterbalance the gain in proteid and salts. Salts in abundance are obtained from

[1] Quoted by Dr. C. Graham, 'Chemistry of Bread-making,' lecture at the Health Exhibition, 1884.

many foods besides flour, and bread is not, as has been stated, a pre-eminently proteid food. It seems wiser, therefore, to adhere to the tradition of centuries, and finely mill the grain so as to obtain white flour and white bread.

Preparations of Wheaten Flour

Of the preparations of flour, *bread* is the most important: of less importance are *biscuits*, *macaroni*, and *vermicelli*.

1. *Bread*

The best bread is made from white wheaten flour. In times of famine or war other starchy foods are added to the flour, to make up the weight of the loaf; these starchy foods are rice, barley, oats, rye, maize, millet, peas, and buckwheat. Under ordinary conditions, these additions are regarded as adulterations, under which heading they will be considered (p. 461).

The processes for making bread are various. The first process, the origin of which is hidden in prehistoric times, consisted in simply mixing the flour with water, and baking. This process is still used in Spain, in India (making 'chupatty'), and in Australia (making 'damper'); leaven was then discovered, and is now used in some countries in the North of Europe. Leaven is dough, with or without an admixture of salt and boiled potatoes, allowed to stand exposed to the air, until decomposition commences. This decomposition is produced by a ferment action on the starch, whereby alcohol and carbonic acid gas are formed. The leaven acts the part of the ferment (presently to be described) in the ordinary making of bread. The modern process of bread-making consists in the use of yeast as a ferment.

(*a*) *Bread-making by Means of Yeast.*—The London system is a long process with three stages:[1]—

1. The preparation of the 'ferment.'
2. The preparation of the 'sponge.'
3. The preparation of the 'dough.'

One sack of flour weighs 280 lb., and 94 to 96 quartern (4 lb.) loaves may be obtained from it; in other words, 280 lb. of flour yield 376 to 384 lb. of bread. The following remarks apply to a sack of flour.

1. The 'ferment' is made with 8 to 12 lb. of the best potatoes, cleaned, cut up, boiled, and made into a thin paste; the temperature of the mixture is then reduced by cold water to about 30° C. (86° F.) To it 2 lb. of flour are added and one quart of brewer's yeast. The process which takes place in this mixture of potato starch, flour, and yeast is that the yeast decomposes the proteids of the flour and the starch of the potato, forming maltose, dextrine, and peptone-like bodies. The process is continued for five hours. The yeast becomes very active with the sugar and proteid food.

2. The 'sponge' is made by mixing one-fourth or one-third of the total quantity of flour into the 'ferment,' the water present being about 30 quarts. Three pounds (48 oz.) of salt are then added. With the best flours the salt is not necessary. If too much be used, fermentation is checked. The chemical process going on in the sponge stage is one of active fermentation; in about five hours the sponge breaks, owing to the development of carbonic acid, i.e. the fermentation has gone a step further than the first stage; from the maltose and dextrine carbonic acid and alcohol are formed. The sponge is allowed to break a second time.

3. The remainder of the flour of the sack (three-fourths or two-thirds)

[1] See lecture, 'Chemistry of Bread-making,' by Dr. Charles Graham, previously quoted, to which lecture I am indebted for the facts stated.

with the remainder of the water (60 quarts to the sack) are now mixed with the sponge and the dough is formed. It rises in an hour, and is placed in an oven at 400 to 450° F. (204° to 232° C.) for an hour and a half. The temperature of the dough itself is not much over 100° C. The chemical processes in the dough stage are not very active; the high temperature stops the fermentation. But it is during this stage that the bread becomes well aërated, and that the aroma and flavour of the loaf are developed. Both these are very important points, and are useful in aiding digestion. The fine aroma and the 'nutty' taste of good bread increase the appetite for food, and moreover do not lead to distaste of the food. The aëration allows the bread to be better heated in the internal parts, so that the loaf is not too sodden, and thus rendered indigestible.

(*b*) *Bread Aërated by Chemical Means* (*non-fermented Bread*).—In one method, sodium bicarbonate and hydrochloric acid are mixed with the dough; the carbonic acid formed expands in the oven, and the bread is aërated.

In another, Dr. Dauglish's system, the water to be mixed with the flour is supersaturated with carbonic acid gas, and mixed with the flour under pressure. The carbonic acid expanding with the heat of the oven aërates the bread. This form of bread is liked by some, but is somewhat tasteless to others.

Baking powders consist of tartaric acid and sodium bicarbonate in different proportions. Church gives as the percentage of these substances in two powders the following: in one, 12·8 per cent. tartaric acid and 11·9 per cent. sodium bicarbonate, with nearly 50 per cent. of rice flour, a little wheat and rye flour, and a trace of common salt; in the other, 27·6 per cent. of tartaric acid, 31·6 per cent. of sodium bicarbonate, with some potato flour.[1]

Unfermented bread, i.e. bread aërated with carbonic acid, is supposed to have the advantage of not containing alcohol, acetic acid, and other bodies, the product of the action of the yeast. It certainly does not contain these; but the advantage is a doubtful one, since the yeast begins the digestion of some of the starch, changing it into maltose and dextrine, and also of some of the proteids, since peptone-like bodies [2] are produced by it.

Chemical Composition of Bread.—From what has been said about the making of bread, it will be seen that bread differs in composition from flour. It is a preparation of flour, indeed, in which the proteids and (to a greater extent) the starch are in part digested; probably albumoses are in greater abundance, and maltose and dextrine, than in the flour. The crust forms not less than 30 per cent. of the loaf. Being the part most exposed to heat, it contains less water than the crumb and more dextrine, owing to the action of the heat into transforming the starch into dextrine. According to Van Bibra, the proteids in the crust of bread form about 9·22 per cent., in the crumb 9·36 per cent. (see Table, p. 460). Even the best bread is slightly acid. Parkes gives the acidity of two samples of good fresh bread as 0·054 and 0·055 per cent. respectively, reckoned as glacial acetic acid. The acidity of good bread may be somewhat higher, but when the acidity reaches 0·18 per cent. the bread ought to be condemned as sour.[3]

Advantages of Bread as a Food.—These advantages are easily summed up. The development of an aroma and of a pleasant taste during the making of yeast bread is a great aid to its consumption. In addition to this the bread is finely divided by the aërating process which it undergoes; digestion is thus aided. Part of the proteids and starch is also digested, so that, as

[1] *Food*, by A. H. Church, M.A., p. 76.

[2] These are probably albumoses, although the exact nature of these bodies has not yet been investigated.

[3] *Hygiene*, pp. 717, 718.

has been already pointed out several times, yeast bread may be considered as a partially digested flour, and from this point of view it must be regarded as superior in a dietary to the non-fermented forms of bread. This is a point often lost sight of in considering the different forms of bread. It is true that cooked starch is very readily digested by the healthy organism, but a partial pre-digestion must be considered an aid to the economy, especially when the complicated feeding of modern life is taken into account.

Table showing Percentage Composition of Bread

—	Water	Proteid	Fat	Starch and dextrine	Sugar	Cellulose	Salts	Proportion of nit. to non-nit. foodstuffs as
Fine white bread .	35·59	7·06	0·46	52·56	4·02	0·32	1·09	1 : 7·5
Coarse bread . .	40·45	6·15	0·44	49·04	2·08	0·62	1·22	1 : 8·4
White bread, average quality (Parkes) .	40·00	8·00	1·50	49·2		—	1·30	1 : 6·3
Wholemeal bread (Church) . .	43·40	10·40[1]	0·30	42·7		1·70	1·50	1 : 4·7
Biscuits (English) .	7·45	7·18	9·28	58·08	17·02	0·16	0·85	—
Navy biscuits (Church) . .	10·20	10·90	1·60	75·00	—	1·20	1·10	1 : 7

The disadvantages of bread as a food are those of flour; it has too little salt (sodium chloride) and too little fat. Salt, as we have noticed, is added in the making of bread, being present to the amount of about half an ounce in each quartern (4 lb.) The deficiency of fat is made up by eating butter and fat bacon with bread; a custom originating in experience and ratified by science.

Preservation of Bread.—After baking, the bread begins to lose water by evaporation. In quartern loaves (with crust on two sides) there is less than 6 per cent. loss in 24 hours; the loss is greater if there is less crust. Stale bread is rendered palatable by moistening and placing in the oven.

For transport the bread is partially dried, the water being reduced to 12 to 14 per cent. (Von Bibra), and softened with water before using.[2]

Plain biscuits are a mixture of flour and water well baked. Fancy biscuits contain butter, eggs, milk, and flavouring agents.

Owing to the prolonged baking, biscuits contain more dextrine than bread, and do not, like bread, contain the products of the action of yeast on the proteids and the carbohydrates.

The composition of plain biscuit is given in the table above. It differs from bread in containing a much smaller quantity of water and a larger proportion of organic foodstuffs—proteids and carbohydrates. Weight for weight, it is therefore more nutritious than bread, and being easily transported is useful as a substitute for bread when this cannot be obtained. It is apt, however, to be tired of.

Macaroni is a preparation of flour. It is made from the 'hard' wheats of France and Italy. The large quantity of gluten present in these hard wheats allows the manufacture of the macaroni as found in commerce.

In composition it contains 13·07 per cent. of water, 9·02 of proteids, 0·30 of fat, 76·77 of carbohydrates, and 0·84 of salts. Macaroni varies slightly in composition. It is a valuable food, not much appreciated in this country.

Vermicelli closely resembles macaroni in its nutritive properties.

[1] Composed of 9·1 per cent. proteids and 1·3 nitrogenous non-proteid substances (?).

[2] For the French preparations of bread, see Parkes's *Hygiene*, p. 280.

Examination of Flour.—Adulterations

Examination of Flour.—Flour is white with a faint yellow tinge, soft to the touch, very slightly coherent, and not gritty. It possesses a faint characteristic smell; when mouldy, or commencing to change, it smells musty or sour. Nearly all flours are slightly acid to test paper when moistened; strong acidity indicates that the starch is beginning to change, forming vegetable acids.

The quality of flour may thus partly be judged by its appearance, but a further examination is necessary in cases of doubt. The amount of water has to be estimated, the amount of gluten, and the kind of bread the flour makes.

Amount of Water.—The water should not be over 15 per cent. The usual amount is about 13 per cent. (p. 456), but it may be as low as 10 and as high as 18 per cent. An excess of water tends to decomposition of the flour.

The amount of water is estimated by taking one gramme of flour and drying in a weighed dish at 100° C. for two or three hours. The flour and dish must be weighed after cooling and the weight of the dish subtracted. The loss of weight in the flour multiplied by 100 gives the percentage of water.

Amount of Gluten.—A weighed quantity of the flour, say 100 grammes, is taken, thoroughly mixed into a thick paste with lukewarm water, then put into a muslin bag, and washed in a stream of running water till all the starch is washed away. The gluten (with some starch) is then removed from the muslin and again washed in water until it gives no starch reaction (blue colour) with iodine. The gluten is then spread out and dried at 100° C. The weight ought to be 8 to 12 per cent. of the flour. The gluten obtained is not, however, pure proteid; it contains some fat and sometimes bran. It is often sufficient to weigh the moist gluten; if this weight be divided by 2·9 it gives the weight of the dried gluten.[1]

The gluten may be separated from the flour in a dish, without using the muslin, but the muslin hastens the process.

The amount of gluten is a test of the bread-making quality of the flour. There are, however, other ways of testing this. The gluten is in one method separated from the flour, put into a tube and then into the baking oven. According to the amount of expansion of the gluten, so is the bread-making quality of the flour judged.[2] Another method suggested by Dr. Charles Graham is the following:—To one ounce of flour four ounces of water are added, and the mixture allowed to stand at the temperature of 26°·5 to 29°·5 C. for two hours. It is then filtered, and one ounce of the last clear portions of filtrate is mixed with one ounce of methylated spirit. A precipitate occurs, consisting of maltose, dextrine, and soluble proteids, and the amount of this precipitate is a sign of the amount of soluble matter produced during the sponge stage of bread making. This method is really an indirect way of estimating the amount of gluten in the flour.[3]

These methods are well supplemented, or even replaced, by making a test loaf of bread from the flour which is being investigated. This bread can then be examined by the methods soon to be discussed.

For examination of the ash see p. 462.

[1] Parkes, *op. cit.* p. 716.

[2] This process is used by a French baker, and is quoted by Dr. C. Graham in his lecture.

[3] Graham, *op. cit.* p. 18.

Parasites and Adulterations of Flour

Parasites, both vegetable and animal, occur in flour and are to be detected by microscopical examination.

The commonest vegetable parasite is a fungus, *Puccinia*, of two or more species. These are recognised by the tubules or hyphæ, on which are placed the spherical sporangia, containing numerous spores. One species of Puccinia causes the *smut* or *caries*: it makes the bread bluish in colour and may produce diarrhœa.

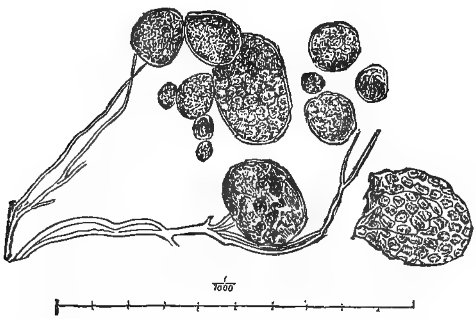


FIG. 107.—Puccinia: hyphæ and spores (Parkes).

Bacteria are also found in decomposing flour.

A mite (*Acarus farinæ*) is also found in flour which is beginning to decompose. It has a rounded body with six or eight legs, and a pointed head supported by protruding mandibles. The eggs are oval.

The weevil (*Calandra granaria*) is much larger than the flour mite, and is readily recognised with the naked eye: it is about five millimetres long and the body is narrow, and has three pairs of legs attached.[1]

The *adulterations* of flour fall into two classes, the *mineral* and the *organic*.

The *mineral* are sand, clay, plaster of Paris, magnesium or calcium carbonate, and alum.

For the ready detection of large quantities of mineral substances, the following method is useful: 5 grammes of flour are shaken with 30 to 40 cubic centimetres of chloroform, the mineral substances sink to the bottom of the tube, while the lighter starch and proteids float. An examination of the *ash* is, however, necessary. When incinerated to white ash, the residue ought not to be more than 2 per cent. of the flour. If the ash is more than this, effervescence with acid (hydric chloride) shows added carbonates of the heavy metals, which must be tested for. A large amount of sulphates in the ash means plaster of Paris (calcium sulphate). Clay is shown by its insolubility in acids and in water. Lead is readily detected by heating in the blowpipe, when a bead is formed, or by dissolving the ash in acid and testing for the metal.

The *organic adulterations* are the starch-containing flours from the other cereals, from Leguminosæ, and from a few other plants. Flour is thus found mixed with—

Barley	Buckwheat	
Maize	Millet	
Oats	Melampyrum	rare admixtures.
Rye	Lolium	rare admixtures.
Potato	Agrostemma (corncockle)	rare admixtures.
Peas and beans	Rhinanthus	rare admixtures.
Rice	Ergot	

The addition of barley, oats, rye, maize, and the other cereals to wheaten flour does not make it harmful; but it lowers the value of the bread made

[1] For an account of the moth (*Ephestia elutella*) which is sometimes found in flour see Parkes's *Hygiene*, p. 277.

from it. The addition of buckwheat, Melampyrum, of Agrostemma, of Rhinanthus, and of ergot, causes the bread made from such flours to be coloured, while the bread containing Lolium and ergot is poisonous. Lolium does not colour the bread.

The detection of the additions to flour rests almost solely on the characters of the starch grain peculiar to each plant. For these characters (see pp. 451–454). But there are other facts which aid, viz. the structure of the envelopes of the grains, which differ in each plant, and part of which is always present even in the best milled grains.

The addition of potato, of peas and beans, of oats, of maize, and of rice, is readily detected by the characters of the starch grains alone. With peas and beans, too, a large amount of cellulose is present, which is detected under the microscope after adding liquor potassæ to dissolve the starch. The detection of barley is, however, much more difficult. The starch grains closely resemble those of wheat in size and shape. The envelopes of the barley grain also closely resemble those of wheat, but they are distinguished by their greater delicacy in structure.

Rye starch grains resemble those of wheat, but the rayed hilum distinguishes them. The rayed hilum is also seen, it must be remembered, in the starch grains of old wheat, but they are not nearly so numerous as in rye flour.

Buckwheat is detected by the small round starch grains and by the structure of the coatings, and especially the large cellulose spaces containing the starch grains. It is an adulteration of wheat from the Baltic. Millet is found as an adulteration of wheats from Asia and Africa.

Flour adulterated with Melampyrum is not altered in colour, but the bread made with it has a smoky-violet tint.

Agrostemma (corncockle) gives bread a greenish colour, while Rhinanthus imparts a bluish-black colour to the bread. The admixture of Melampyrum, Agrostemma, or Rhinanthus does not cause poisonous symptoms.

Lolium temulentum (darnel), however, makes the bread poisonous. The symptoms produced are to some extent gastro-intestinal, but are chiefly referable to the nervous system. Thus there is a sensation of heat in the throat, vomiting, headache, giddiness, staggering, tremulous gait, impaired vision, and symptoms of collapse. Convulsions, hallucinations, delirium, and paralysis may also be observed.

Lolium may be detected by the following tests. An alcoholic extract is of a greenish colour and disagreeable taste. The alcoholic extract of wheaten flour is yellowish, and has not a disagreeable taste.

Vogel says that the following reaction is given with flour adulterated with Agrostemma, Lolium, beans, or ergot. If to two grammes of the flour 10 cubic centimetres of 70 per cent. alcohol are added, and then 5 per cent. hydric chloride, an orange yellow colour is obtained.[1] Ergot of rye is occasionally mixed with wheaten flour, but not in this country. It is of most importance in connection with rye bread, which is so commonly used on the Continent (see p. 466).

Examination of Bread

The crust of bread should be yellowish brown, firm, and not aërated. The crumb of bread is porous and elastic. There should be no sour smell.

Potato-flour makes bread soft, while barley flour makes it dry.

Amount of water is important to estimate. It varies from 30 to 40 per cent. In bad bread it is 50 per cent.

[1] On this and other points in detail, see A. E. Vogel, *Nahrungs- und Genuss-Mittel aus dem Pflanzenreiche*, Vienna, 1872; *Die Untersuchungen des Mehles*, 1880.

The *acidity of bread* has already been discussed (p. 459).

The *ash* of bread ought never to be over 3 per cent. Potatoes render the ash alkaline, due to sodium carbonate.

Alum is added to bread to improve the colour and to stop fermentation. Ordinary bread may contain a small quantity—about 0·005 per cent.—of phosphate of aluminium (Wanklyn). This amount must, therefore, be deducted from the alum found in the bread examined, the result giving the amount of the salt added. The alum present in alumed bread varies—12 grains in a quartern loaf, or even 41·6 grains.

Copper sulphate is readily detected by testing a watery extract of bread with potassium ferrocyanide: a brown colouration or precipitate is the result.

The microscopical examination of bread is important. It may show fungi, with their mycelium and spores (Penicillium), or bacteria in decomposing bread.

The deleterious effects of bad bread are due partly to its indigestibility and partly to the poisons contained in it.

Bread containing too much water, sodden bread, is indigestible, causing a sense of weight in the stomach, &c. Acid bread also disagrees. Acidity is due chiefly to the fatty acids, and these cause acidity and increase this symptom if already present. Acid bread may also lead to diarrhœa. The symptoms produced by decomposing bread are those of decomposing food generally, referable to the gastro-intestinal tract. The presence of fungi (not bacteria) is also said to lead to diarrhœa; their presence shows that the bread is beginning to decompose, and it is not known whether they are of themselves harmful or whether the bacteria present in such bread are the real poisonous agents.[1]

Alumed bread causes dyspeptic symptoms, with constipation, probably only when there is a large amount of alum present in the bread. Alum is added to inferior flours, and it is a question how far these flours themselves are really responsible for the symptoms. There is no doubt that alum does constipate, and not only that it is itself no food, but that it combines with some of the phosphates of the bread forming insoluble aluminium phosphate. Its use is therefore rightly declared illegal.

It is not known whether the small amount of *sulphate of copper* sometimes present in bread causes harmful symptoms.

Lead poisoning is, however, rarely a consequence of the eating of bread. It has occurred where the holes in the millstones have been repaired with the molten metal, and where old wood which had been painted has been used for heating the baking oven.[2]

The symptoms produced by bread containing *Lolium temulentum* have already been described. For those caused by *ergotised bread* see p. 467.

Barley (*Hordeum vulgare*)

The barley of commerce exists in two forms—the pot barley, which is simply the husked grain, and the pearl barley, which is the cleaned grain, somewhat polished by the process of cleaning. Its grain is also ground into flour, and is called prepared barley. It is liable to adulteration.

As a Food.—Barley is very nutritious. In percentage composition it closely resembles wheaten grain. There is, however, a great difference in the

[1] *Aspergillus glaucus* seems to poison horses, causing paralysis. See Parkes, *op. cit.* p. 291.

[2] See Alford, *Sanitary Record*, 1877.

character of the proteids present. These do not, like those of wheaten flour, form gluten on the addition of water; they exist solely in the form of what some agricultural chemists call 'soluble albuminoids.' According to Ritthausen, they consist of gluten-casein, gluten-fibrin, mucedin, and albumen.[1] According to my own researches, they consist of globulin, albumose, and albumen. Ritthausen alone is responsible for the body named mucedin, which is supposed to be vegetable mucin.

This chemical difference between the proteids of wheat and barley very probably also means a nutritive difference; but it is almost impossible to speak definitely on this point. It is, however, evident that the great advantage of wheaten flour as a food is that it can be made into bread, which, as we have previously insisted upon, is not only a very palatable, but a digestible and a partially digested food.

A weak solution of barley starch is added to milk in infant feeding to diminish the size of the curds found in the stomach. As far as is known, the *disadvantages of barley* as a food rest almost solely in its insipidness; it is, like other vegetable food, liable to cause digestive disturbance if too freely partaken of.

OATS (*Avena sativa*)

Oatmeal is a valuable food, as is evidenced by its extensive use among the Scotch peasantry, with whom, indeed, it was at one time the chief food.

The advantage of oatmeal as a food depends on the fact that it can be taken for long periods without distaste, and that the proteid constituents are in large amount, the carbohydrate in fair proportion (less, however, than in wheat or barley), while there is a relatively large amount of fat present. This last foodstuff distinguishes oatmeal greatly from wheaten flour or barley. The proteids present are called gliadin and gluten-casein (avenin). They differ, like those barley, from the proteids of wheat in not forming gluten on the addition of water. On referring to the analysis of oatmeal on p. 456, it will be seen that the proportion of the proteids to the non-nitrogenous organic foodstuffs in it (1 : 5·4) more nearly approaches the normal relation in a dietary (1 : 3½ or 4) than that in barley or wheat. It is therefore more suitable to constitute a large part of the dietary than either of these cereals, if it were not for certain drawbacks to its use. One of these is that oatmeal contains a large quantity of cellulose, which is apt to irritate the intestines, and at any rate interfere with the complete digestion and absorption of the foodstuffs. The coarse oatmeals contain more cellulose than the fine preparations, and are thus more liable to cause intestinal irritation. Oatmeal requires salt. The pericarp of oats contains an alkaloidal principle, which is a stimulant to the muscles; it causes excitement in horses.[2] This alkaloid may perhaps account for some of the beneficial effects of the use of oatmeal in those who do hard manual labour, as well as in the hardy fighters of the Highlands.

Oatmeal is adulterated with barley, the admixture being readily detected by attention to the size and shape of the starch grains (see p. 454). Rice and maize may also be found in the meal; the starch grains are characteristic in both. The husks of wheat and barley may also be added.

[1] For Ritthausen's laborious researches on the composition of cereals, &c., see his *Die Eiweisskörper der Getreidearten*, &c., 1872. Since Ritthausen's work the nomenclature of the proteids has altered, and the researches of recent years render a re-examination of the proteids of plants necessary.

[2] See Brunton's *Pharmacology*, 3rd ed. p. 1056.

Rice (*Oryza sativa*)

The grains are husked, the cuticle removed by machinery, the dust brushed off, and the surface of the grain polished to a greater or less extent. Many varieties exist in commerce, the better class of which, Java, Japan, Carolina, Patna, are well polished, while the inferior varieties, Rangoon, &c., are not so well cleaned. These inferior varieties vary in colour, being reddish sometimes, contrasting greatly with the yellowish-white colour of the better varieties. Rice, therefore, ought to be well cleaned, with a certain polish on the surface, free from dust and with the grains whole and not broken. Uncleaned or partially cleaned rice is in use among the peasantry in India and Burmah.

As a food, rice must be considered almost solely as a starchy food. The percentage of proteids is small (p. 456), while that of the carbohydrates is very large—over 78 per cent. The salts are also greatly deficient. When rice is taken, therefore, salt has to be added to supply the deficiency of mineral foodstuffs, meat or peas and beans to supply the deficiency of proteid, and animal fat (butter, &c.) to supply the fat necessary. Taken in such a mixture, rice is a valuable food; when taken alone, it has to be consumed in too large quantities to supply the amount of proteid necessary for the body.

The cooking of rice is important; it should never be boiled, but steamed so that none of the proteid is lost.

Rye (*Secale cereale*)

Rye is a more important food in the northern countries of Europe than in our own country. It is extensively grown abroad, where it is made into bread—Schwarzbrod, Pumpernickel, &c.—and is the bread of the poorer classes. In this country rye grain is chiefly used for malting. Rye is a very nutritious grain: in percentage composition it closely resembles wheat (see p. 456). The proteids present[1] form a kind of gluten on the addition of water, but not to so great an extent as in wheat, nor can the gluten be so readily separated.

The bread made from rye is dark in colour, heavy, and very acid; it retains its moisture a long time.

Percentage Composition of Rye Bread

—	Water	Proteid	Fat	Sugar	Starch	Cellulose	Salts
German rye-bread	42·27	6·11	0·43	2·31	46·94	0·49	1·46
Pumpernickel[2]	43·42	7·59	1·51	3·25	41·87	0·94	1·42

The percentage composition does not, therefore, differ greatly from that of wheaten bread (see p. 460). The great drawbacks to rye bread are, however, that it is heavy and acid, and thus indigestible and liable to cause diarrhœa. It has a peculiar odour and taste, and one not pleasant to those accustomed to wheaten bread. A better bread is made by mixing wheaten flour with rye in the proportion of two to one.

[1] These proteids, according to my analysis, are globulin and albumose—the same, therefore, that occur in wheaten flour. Ritthausen calls them vegetable fibrin, casein, and albumen (*op. cit.*)

[2] The blackbread of Northern Germany, made from the whole of the rye grain.

As regards the digestibility of rye bread compared with white bread, G. Meyer[1] has shown that with white bread a large proportion of the proteids and salts is absorbed than with Pumpernickel or with Munich rye bread, and that this latter form of rye bread is more digestible than the North German commodity. There can be no question, therefore, of the superiority of wheaten bread.

Rye grain is subject to a disease caused by a fungus, the *Claviceps purpurea.* The growth of this fungus causes the grain to enlarge and become black, producing what is known as *ergot of rye.* The ergot gets mixed with the healthy rye grain, and its presence in the bread leads to a varying train of symptoms called *ergotism.* This disease, which is practically unknown in this country, is more common in those countries where rye bread is a staple food, but it is getting less common now owing to the greater care in the selection and the milling of the grain.

Ergotism occurs in epidemics, and is partly due to the ergot and partly to the deterioration (weight for weight) of the food by the presence of the fungus. The symptoms begin with loss of appetite, vomiting, and diarrhœa, and then assume one or two forms. In one form, gangrene of an extremity is the chief symptom ; this is no doubt rightly ascribed to the contraction of the arterioles, caused by ergot cutting off the blood supply to the part. In the other form the symptoms are referable to the nervous system. There is giddiness with loss of sensation in the extremities and abnormal sensations in the skin. There may also be convulsions, and definite alterations of the postero-lateral columns of the spinal cord have been found.

Ergot may be detected in the flour by the microscope by which the mycelium and spores of the fungus will be seen. The following chemical tests have been suggested. To 10 grammes of flour, 15 grammes of ether are added and 20 drops of dilute sulphuric acid (1 in 5) ; the mixture is shaken, and on adding 5 drops of a saturated solution of sodium bicarbonate a violet colour is developed (Hoffman and Wolff). By another method a paste of the flour is made with an alkali, and dilute nitric acid added to excess ; the mixture when neutralised gives a violet red colour (Laneau).

Maize (*Zea maïs, Indian Corn, and Corn*)

This is an important food in some countries—those of Southern Europe and of America—but it is not much used in this country. In Italy it is called polenta. The percentage composition of the maize flour (p. 456) shows it to be a very nutritious food ; and indeed in some parts maize cakes take the place of bread as the staple vegetable food. Made into cakes, it is of course not to be compared to bread either for palatableness or digestibility ; but people are said soon to get accustomed to its use. It is best taken as porridge, made either from corn flour, oswego, or from the ground whole-maize. In the preparation of corn flour, not only is the cellulose removed, but a large quantity of the proteids ; so that, although more digestible than whole maize, it contains a smaller percentage of proteid foodstuffs.

Like oats, maize contains a large quantity of fat. Some of its proteids have been described under the name of *Zeïn,* but what this body really is, is not at present known.

The deleterious effects of maize depend partly on imperfect cooking, thus causing indigestion, and partly on putrefactive decomposition.

Putrefied maize is said to contain at least two poisonous principles (probably alkaloidal in action). One of these produces muscular spasms, the other

[1] Quoted by König, *op. cit.* See also the original paper in *Zeits. f. Biologie,* 1871, p. 1.

has a narcotic action. The proportion in which the two substances relatively exist in the decomposed maize appears to vary.

A disease of maize, whether due to the fungus *Sporisorium maïdis* (Verdet) or the so-called *Bacterium maïdis*, seems to be one of the factors in the production of *pellagra*, a malady occurring in Lombardy. There may be other factors, such as impoverished food; for not only do some of the symptoms (such as serous effusions, &c.) resemble those of scurvy, but the main treatment of the disease is one of a generous diet of fresh animal and vegetable food. Among the many symptoms of pellagra, the erythematous affection of the skin, from which the disease derives its name, seems to be the least important. There are gastro-intestinal symptoms, such as nausea, diarrhœa, heat of epigastrum, and a voracious appetite, but the chief symptoms are nervous. The subjects of pellagra suffer chiefly from melancholia, with stupor and suicidal tendencies, arising in some cases from the intolerable burning sensation of the skin. Fainting is common, muscular spasms and contracture are also noticed; some cases, indeed, closely resemble spastic paralysis, showing an affection of the lateral columns of the spinal cord. The nervous affections in pellagra are therefore as important as those observed in cases of ergotism.[1]

Millet and Buckwheat

Millet is a food largely used in hot countries, Italy and the Iberian Peninsula in Europe, in Africa, and in parts of Asia (India, China, &c.) It is obtained from different plants: thus the common millet is prepared from *Panicum miliaceum*; the Indian or small millet (Guinea-corn, Dharra) from *Sorghum vulgare*; Italian millet is from *Setaria italica*;[2] German millet from *Setaria germanica*; spiked millet from *Pencillaria spicata*; and golden-coloured millet from *Sorghum saccharatum*.

The chemical composition of the seeds of these different grasses is very similar. The salts consist, like other cereals, largely of phosphates, but also contain silica.

Percentage Composition of Millet and Buckwheat (shelled)

—	Water	Proteid	Fat	Carbo-hydrate	Cellulose	Salts	Proportion of nit. to non-nit. foodstuffs as
Panicum miliaceum (common millet)	11·79	10·51	4·26	68·16	2·48	2·80	1 : 6·89
Sorghum vulgare (small millet)	11·46	8·96	3·79	70·25	3·59	1·95	1 : 8·20
Setaria italica (Italian millet)	12·04	7·40	3·87	74·21	1·37	1·11[3]	1 : 10·50
Sorghum saccharatum (golden-coloured millet)	15·17	9·26	3·36	67·99	2·51	1·71	1 : 7·70
Polygonum fagopyrum (buckwheat)	12·68	10·18	1·90	71·73	1·65	1·86	1 : 7·10

From this composition, millets are evidently a nutritious food; millet-bread can be made, and is a substitute for wheaten bread.

Buckwheat (nat. ord. Polygonaceæ) is less nutritious as a food than its composition would indicate; this is eminently the case if the seed is not shelled, as the coating contains a large amount of cellulose. If the whole seed be crushed, and used, cellulose is found to be present to the extent of

[1] See Tuczek, *Deutsche med. Wochenschr.* 1888, No. 12, for the nervous symptoms, and Neusser, *Wien. med. Wochenschr.* 1887, No. 5.

[2] *Panicum italicum.*

[3] From the analysis of O. Kellner, quoted by König, *op. cit.*

14·32 per cent., while in the shelled seed it forms 1·65 per cent. of the food.

Raggy is obtained from *Eleusine corocana.* It is used largely in some parts of India, and is said to be very nutritious.

Chestnuts (*Castanea vesca*)

Belonging to the same class of foods that have just been considered is the edible chestnut. The amount of proteids and carbohydrates present closely resembles that present in the cereals. Thus there are 10·76 per cent. of proteids, 2·90 per cent. of fat, 73·04 per cent. of carbohydrate (almost solely starch), 2·99 of cellulose, 2·97 of salts, and 7·34 of water in the shelled seed. Chestnuts are therefore chiefly a carbohydrate food; to a secondary extent, also a proteid food. In some parts of the Continent (Germany and Spain) they form a staple food of the population, replacing bread.

CLASS II

The second class, into which we have divided vegetable foods, include those which contain a large percentage of proteid and of carbohydrate; so that they are both proteid and carbohydrate foods. To this class belong the seeds of the Leguminosæ, which are used as food, and a Peruvian food—white quinoa, obtained from the *Chenopodium quinoa.* As a subdivision of this class will be considered certain vegetable products, which, besides containing a large amount of proteid, contain a large amount of fat with a varying amount of carbohydrate. These vegetable foods may be described as oily seeds; such as linseed, the walnut, the ground-nut, &c. They are not of much importance in this or other civilised countries as food, but it is well to bear in mind their nutritive importance in times of scarcity of the staple foods.

1. With regard to the seed of the *Leguminosæ,* it must be remembered that they are used as food in two states, fresh and dried, and that the percentage chemical composition differs in the two conditions owing to the large amount of water present in the fresh seeds.

All these seeds, too, possess an aroma which is intensified during cooking; the older and drier the seed the greater the aroma up to a certain point.

The character of the *proteids* present have not been much investigated. These bodies are described as *legumin* and *conglutin* (see p. 450), and are sometimes called vegetable caseins. But it is probable (see Vines, already quoted) that the greater part of the legumin and conglutin is derived during extraction from the globulin and albumose present in the seed.

There is a large amount of cellulose present in the dried seeds, a circumstance which leads to diminished digestion and absorption. In the salts present, the phosphates and potassium and calcium predominate, as in other vegetable foods, over the chlorides and sodium. Most of these seeds, as other vegetable foods, contain a small percentage of iron, combined probably with an organic body. White quinoa is particularly rich in iron (see p. 455). The *digestibility* of the seeds of leguminous plants is an important point. M. Rubner in a series of experiments found that from about 21 to 30 per cent. of the nitrogen of peas was passed out undigested in the fæces, as compared with 13 to 14 per cent. of the nitrogen of white bread, and about 17 per cent. of blackbread. Rutgers' experiments showing the unsuitability of leguminous seeds, as replacing animal proteids, have already been described. The mode of preparation of the dried leguminous seeds is all-important from a diges-

tive point of view. Strümpell,[1] for example, found that when ground into meal and mixed with milk, butter, and eggs as in the ordinary mode of cooking, the seeds of Leguminosæ were more completely digested than when cooked whole and by themselves. This, of course, means, that in the first case the food was more finely divided and the digestible foodstuffs removed more completely from their indigestible (cellulose) covering. These remarks do not apply to the fresh seeds—such as peas—which are rendered quite soft and succulent by cooking.

The *disadvantages* of these seeds as food are, that they are liable to cause indigestion if partaken of in too large a quantity—leading to acidity, flatulence, and diarrhœa. They lack, too, fat and sodium chloride ; these ought to be added in the cooking.

Percentage Composition of Seeds of Leguminosæ, &c.

—	Water	Proteid	Fat	Carbo-hydrate	Cellulose	Salts	Proportion of nit. to non-nit. foodstuffs as
1. Peas (*Pisum sativum*):							
Green	78·44	6·35	0·53	12·00	1·87	0·81	1 : 2
Dried (average) . .	13·92	23·15	1·89	52·68	5·68	2·68	—
Pea flour	11·41	25·20	2·01	57·17	1·32	2·89	1 : 2·3
2. Beans (*Vicia faba*) . .	13·49	25·31	1·68	48·33	8·06	3·13	—
Bean flour	10·29	23·19	2·13	59·37	1·67	3·35	1 : 2·6
3. Haricot beans (*Phaseolus vulgaris*)	11·24	23·66	1·96	55·60	3·88	3·66	1 : 2·4
Fresh French beans .	88·75	2·72	0·14	6·60[5]	1·18	0·61	1 : 2·4
4. Lentil beans (*Ervum lens*)	12·33	25·94	1·93	52·84	3·92	3·04	—
Flour	10·73	25·46	1·83	57·35	2·01	2·62	1 : 2·3
5. Soja beans (yellow) (*Soja hispida*, var. *tumida*) .	9·89	33·41	17·68	29·31	4·67	5·10	1 : 1·4
6. Yellow lupin seeds[2] (*Lupinus luteus*) . . .	13·98	38·25[3]	4·38	25·46	14·12	3·81	—
7. *Lathyrus sativus* . .	12·74	24·08	2·38	51·38	6·60	2·82	—
8. White Quinoa[4] (*Chenopodium Quinoa*) . . .	16·01	19·18	4·81	47·78	7·99	4·23	1 : 2·7

There is a great difference between the composition of fresh peas and dried: roughly, 1 part of dried peas by weight equals 4 parts of green in proteid and carbohydrate.

Soja beans, from the large amount of fat they contain, approximate in composition to the oily seeds presently to be considered.

Percentage Composition of Oily Seeds

—	Water	Proteid	Fat	Carbo-hydrate	Cellulose	Ash	Proportion of nit. to non-nit. foodstuffs as
1. Linseed (*Linum usitatissimum*)	9·23	22·57	33·64	23·23	7·05	4·28	1 : 2·5
2. Walnut (*Juglans regia*) .	7·18	15·77	57·43	13·03	4·59	2·00	1 : 4·4
3. Hazel nut (*Corylus avellana*)	7·11	17·41	62·60	7·22	3·17	2·49	1 : 4·0
4. Sweet almond (*Amygdalus communis*)	6·02	23·49	53·02	7·84	6·51	3·12	1 : 2·6
5. Pea- or ground-nut (*Arachis hypogæa*) (shelled) . .	6·95	27·65	45·80	16·75	2·25	2·64	1 : 2·2

[1] *Centralb. f. die med. Wissensch.* 1876, p. 47.

[2] The composition of blue and garden lupin seeds is very similar.

[3] Minus 2·25 per cent. for nitrogenous non-proteid bodies, leaving the proteid 36 per cent.

[4] Analysed by Voelcker, 1857.

[5] 1·16 sugar.

The character of the *oily seeds* has already been described. They are not much used as food, and are usually eaten in this country only in small quantities. In some countries, however, peanuts form almost one of the staple foods.

From their close texture these seeds are indigestible; and they do not cook well.

CLASS III

To this class belong vegetable foods which are chiefly used as yielding carbohydrates. The commercial starches and sugars (sago, arrowroot, &c.) belong to this class. They have already been considered (p. 451.)

The next important member of this class is the potato; of very subsidiary importance as food are beetroot and Jerusalem artichoke. Many fruits yield a large quantity of carbohydrates (sugars), but they cannot be considered as carbohydrate foods of prime importance.

The potato is the tuber of *Solanum tuberosum,* and is an absolute necessity as a food to the poor peasantry of some countries—as Ireland. Its cultivation free from disease, to which it is very subject, is of great economic importance to these people, as the loss of the potato crop means starvation to them.

In chemical composition, potatoes show a small proportion of proteids and a large proportion (for a fresh food) of starch, while the salts consist, as in other vegetable foods, of an excess of phosphates and potassium over sodium chlorides.

The juice of the potato is acid, due to the vegetable acids (especially citrates), partly free and partly in combination with the alkali metals (potassium, sodium, calcium).

As a food, potatoes yield carbohydrates and act as an antiscorbutic.

Percentage Composition

—	Water	Proteid	Fat	Carbohydrate	Cellulose	Ash	Proportion of nit. to non-nit. foodstuffs as
Potatoes	74·98	2·08	0·15	21·01	0·69	1·09	1 : 10·0
Beet (*Beta vulgaris*) . .	82·25	1·27	0·12	14·40	1·14	0·82	1 : 11·4
Jerusalem artichoke (*Lolium tuberosum*)	79·24	1·76	0·14	16·29	1·49	1·08	1 : 9·3

Potatoes are boiled or roasted in their skins so that none of the salts is lost; they may also be steamed.

Examination of Potatoes.—The quality of the potato is judged by its specific gravity and by the absence of the fungus, *Phytophora infestans*, which causes 'potato murrain.'

Parkes[1] gives the following table of the quality of potatoes as tested by their specific gravity:—

Below 1068	The quality is very bad	
Between 1068–1082	,,	inferior
Between 1082–1105	,,	rather poor
Above 1105	,,	good
Above 1110	,,	best

Parkes also gives the following ready, if somewhat rough, method of taking the specific gravity, by means of an ordinary urinometer:—

[1] *Op. cit.* p. 300.

Take a sufficient quantity of water, and dissolve in it $\frac{1}{2}$ oz. to 1 oz. of salt, and take the specific gravity; then add another $\frac{1}{2}$ oz. or 1 oz. and take the specific gravity again. The operation is repeated until the amount of salt added is found, with which the specific gravity will be definitely increased. Then salt enough may be added to bring the specific gravity up to the desired amount, i.e. the specific gravity of the potato.

The *fungus* is detected by the microscope. Partly diseased potatoes may be utilised, either by obtaining the starch from them by washing or by cutting in thin slices and drying in hot-air chambers: they will then keep.

Potatoes may be preserved by peeling, slicing, and placing in molasses or drying and granulating.

CLASS IV

This class of vegetable foods contains articles of diet which supply water, vegetable acids, and salts to the organisms. It may be divided into two groups, succulent vegetables and fruits.

To all succulent vegetables common salt is added in the cooking, and to the majority butter is a valuable addition. Besides the nutritive value of vegetables, there is another use and not an unimportant one; they give relish to the food, and thus act like the other food-accessories, shortly to be discussed. Of these the different varieties of salads may be mentioned: lettuce, endive, mustard and cress, primrose, and dandelion, with onions and celery, &c., which possess pungent aromatic principles.

Of the ordinary vegetables used it will be sufficient to give the composition of turnips, carrots, cabbage, spinach, and cauliflower; the other vegetables are closely similar in composition.

Percentage Composition of Vegetables

—	Water	Proteid	Fat	Carbohydrate	Cellulose	Salts
1. Turnips (*Brassica rapa rapifera*)	90·78	1·18	0·22	5·89	1·13	0·80
2. Carrots (*Daucus carota*)	86·79	1·23	0·30	9·17	1·49	1·02
3. White cabbage (*Brassica oleracea*)	89·97	1·89	0·20	4·87 [1]	1·84	1·23
4. Spinach (*Spinacia oleracea*)	88·47	3·49	0·58	4·44 [2]	0·93	2·09
5. Cauliflower (*Brassica oleracea botrytis*)	90·89	2·48	0·34	4·56 [3]	0·91	0·83

The absence of fresh vegetables in a diet leads to the production of scurvy. The dried vegetables sold are antiscorbutic; they are serviceable for making soups, hashes, &c.

Little need here be said of the composition of *fruits*. They are rich in water, vegetable acids, and salts, and are eminently antiscorbutic (especially the lemon). Some contain large quantities of sugar (the banana, e.g.); others are rich in oil (the mature cocoa-nut). But, except for their antiscorbutic properties and their pleasant taste, they are quite subsidiary as articles of diet.

Lemon-juice, Lime-juice, Vinegar

1. *Lemon-juice* is one of the most important antiscorbutics, and its use in the Navy and mercantile marine has practically eradicated scurvy from among sailors.

[1] Consisting of 2·29 per cent. sugar and 2·58 per cent. other carbohydrates.
[2] 0·10 per cent. sugar, 4·34 per cent. other carbohydrates.
[3] 1·21 per cent. sugar, 3·34 per cent. starch, &c.

Both lemon- and lime-juice contain a large proportion of citric acid, with some malic acid, sugar, and proteid. The citric acid is the important constituent.

Percentage Composition of Lemon- and Lime-juice.

—	Total solids	Consisting of Citric acid	Consisting of Ash	Sulphuric acid	Sp. gr.
Lemon-juice, from *Citrus limonum* .	8·597	6·822	0·259	0·002	1032
Lime-juice, from *Citrus limetta* . .	9·222	7·201	0·419	0·002	1035

To half a pint of lemon-juice one ounce of brandy is added as a preservative. When administered it is diluted and mixed with sugar. The daily quantity to be taken as an antiscorbutic (when fresh vegetables are unprocurable) is one ounce.

Adulterations.—Both lemon- and lime-juice are liable to decomposition and to adulteration. The juice ought to be clear, with an acid but not bitter taste, and the aroma of the fruit.

Lemon-juice is manufactured: a solution of citric acid in water flavoured with essence of lemon is made.

The juice is watered; the specific gravity and the acidity (as tested by standard alkaline solution) detect this adulteration.

Sulphuric acid is the most important adulteration. It may be present up to 0·434 or even 0·825 per cent. (Hassall). It is detected by acidulating with hydric chloride and adding barium chloride, when the insoluble barium sulphate is thrown down.

Hydrochloric acid and *nitric acid* are sometimes added.

Tartaric acid is detected by adding acetate of potassium; on standing, the acid potassium tartrate will be precipitated in crystals.

2. *Vinegar* comes under the same heading as lemon-juice, although it is not so powerful an antiscorbutic.

Vinegar is of two kinds—wine vinegar and malt vinegar. The chief variation in composition is the amount of acetic acid (reckoned as glacial acetic acid) the different vinegars contain. The percentage of acetic acid ought not to be below 3 per cent.; in the best vinegars it may be as high as 6 per cent. A small quantity of sulphuric acid is added to English vinegar.

Percentage Composition of Vinegar

—	Sp. Gr.	Alcohol	Extract	Acetic acid	Tartaric acid	Tartar	Glycerine	Ash
Ordinary vinegar .	1016–1019	trace	0·430	4·02	—	—	—	0·113
Wine vinegar .	1015–1022	1·05	1·066	5·77	0·149	0·124	0·211	0·184

Vinegar is diluted with water; the specific gravity (which is lowered) and the degree of acidity detect this.

Sulphuric acid in excess is detected by barium chloride and hydrochloric acid. Copper, common salt, and lead may be detected by the appropriate chemical tests.

The use of vinegar is that, like other vegetable acids (citric, &c.), it tends to maintain the alkalinity of the blood and the liquids that bathe the tissues.

The acetic acid is converted into carbonate in the body. In doses of from half to one ounce daily, vinegar is an antiscorbutic. It may be mixed with the food and even taken as a drink when much diluted.

Scurvy (*Scorbutus*)

Scurvy is an important disease in connection with food. It has been several times referred to. Many different theories have been brought forward to explain the pathology of the disease, but none of these can be considered quite satisfactory. In scurvy there is a profound change in the blood, the result of which is seen in effusion of blood (ecchymoses) in various parts and in fibrinous exudation in the muscles and gums, and in a condition of anæmia of all the tissues. There seems no doubt that this change in the blood is the chief pathological factor in the disease. Speaking from a chemical point of view, a change in the blood may be brought about either by an altered nutrition of the tissues or of a particular tissue, or by an alteration in the quantity and quality of the food absorbed into the blood-stream. There is much evidence to show that the change of the blood in scurvy is due to the quantity and especially to the quality of food eaten. Thus we have the strong evidence of scurvy present in sailors (at a period, now happily past), who for long periods were fed both insufficiently and with a diet chiefly consisting of salt pork and biscuit. Here the deficiency in the diet was that of fresh vegetables, to the absence of which scurvy has been ascribed. It is known that on a diet of meat and fat alone scurvy may appear, and cereals and the seeds of Leguminosæ have no antiscorbutic power. The food principle in vegetables to which are ascribed antiscorbutic property are the vegetable acids—citric, tartaric, acetic, malic, lactic—and there is some reason for this. According to Busk and Garrod, the deficiency of potash in the system is the basis of scurvy: potassium salts (except those of vegetable acids) are, however, not antiscorbutic.

Ralfe states that the alkaline salts of the blood in scurvy are absolutely decreased. Now the chief source of alkalinity in the body are the vegetable acids just mentioned, for they are changed into carbonate in the system and combine in this state with potassium and sodium, thus forming alkaline salts. Add to this the fact that articles of diet containing these acids or their salts are the best antiscorbutics, and we are almost driven to the conclusion that it is the absence of those important principles in the food which is the main cause of scurvy, especially as this absence means, as a rule, a general deficiency of the diet. This idea is not against the fact that fresh meat may also be antiscorbutic, because fresh meat contains a fair quantity of sarco-lactic acid.

The following may be mentioned as antiscorbutics:—Fresh vegetables, such as potatoes, cabbage, cauliflower; fresh fruit; lemon-juice; dried vegetables, although these are not so useful as fresh; vinegar; and the alkaline salts of the vegetable acids, these, however, not being nearly so useful as good lemon- or lime-juice.

FOOD-ACCESSORIES

Almost as important to civilised man as the foodstuffs which are necessary for existence are substances which enable the food to be taken with relish; such substances may appropriately be called food-accessories. These in many instances contain aromatic bodies, to which their action is due. The smell of well-cooked meat is decidedly appetising; the absence of aroma in badly cooked or over-cooked meat certainly diminishes its consumption. Many other substances act as relishing agents through the aromatic bodies contained in them, the effect in the brain through the special senses affecting the digestive organs. On the other hand, some of these food-accessories have

a special action on the central nervous system, a stimulant or a sedative effect, which is in some cases their chief action. Such food-accessories are alcoholic beverages, tea, coffee, &c. A third action, which may be ascribed to food-accessories, is that of affecting the secretion of the digestive juices, and of acting directly on the chemical processes of digestion.

It is not surprising that, with increase of civilisation and its attendant high development of the special senses and the central nervous system, special stimulants of these parts of the nervous system should be in common use. But it is a remarkable fact that the use of food-accessories having such effects as have been described is universal in the world, in savage as well as in civilised nations. The civilised man has the advantage over the savage in the refinement of his food-accessory stimulants, but not in the quantity of them he utilises.

We may, from what has been said, usefully divide food-accessories into aromatic principles (which affect the digestive system through the central nervous system), into those which directly affect the central nervous system after being absorbed, and into those which directly affect the digestive system. The aromatic principles are often associated with substances which have one or other of the two last actions.

As examples of the aromatic principles, we may cite the aroma of cooked meat, especially roasted meat, an aroma due to an unisolated principle, sometimes called osmazome. The aroma differs in each variety of meat; that of beef is different from that of mutton, of goat's flesh, of pork, &c.; the cooked blood, too, has a different aroma in each animal. This actual aroma is most marked in animal foods; with ordinary vegetable foods, as a rule, it is less marked. The taste of well-made bread (the 'nutty' flavour) is a well-marked characteristic of it, and is no doubt not only due to an aromatic principle, or aromatic principles, but also to the mixture of dextrine, starch, &c., with sugar and the acids which have been described as the products of the activity of yeast. Most of the other cereals have little aroma, and flavouring agents are usually added to them, the commonest being butter and common salt. The leguminous seeds have, as a rule, a well-defined aroma. Some other vegetable products are used almost solely as food-accessories, such as onions, spices, &c. These, however, have probably another and more important action, viz. that of directly stimulating the flow of the digestive juices; a subject to be considered later.

To the second class of food-accessories which we have made belong the most important articles of diet under this heading, viz. those which have an effect on the central nervous system; such as all alcoholic beverages, tea, coffee, cocoa, &c., and beef-tea to a less degree. They all have, however, properties which would entitle them to be placed under all three classes of food-accessories. For not only do they act on the central nervous system, but they often possess a delicate aroma, and they have, as we shall see, a powerful effect on the digestive juices and the chemical processes of digestion. But there seems little doubt that the object for which they are taken by mankind is that of affecting the central nervous system.

This they do in two ways: small doses stimulate, large doses depress; medium doses may be said to act as a sedative. In the alcoholic beverages these effects are due to the alcohol present in them; in tea, coffee, cocoa, &c., they are due to the active principles caffeine and theobromine. Both alcoholic beverages and tea, and its congeners, have other effects besides those due to their respective active principles. These effects are, however, best considered under another heading.

It is difficult to give physiological reasons for the custom of taking cerebral stimulants and sedatives as food-accessories. If it is not simply a question of morals, as some consider it is, one explanation may be given. Man, both in the savage and in the civilised state, is accustomed to eat large meals, which tend to diminish the activity of the central nervous system, and thus to diminish the digestion of the ingested food. Cerebral stimulants may by keeping up the activity of the central nervous system aid in the prolonged digestion of a large meal. It is not simply that alcoholic stimulants, to take an example, in moderate doses increase the flow of the digestive juice, and thus aid digestion, because a slight excess of the ordinary alcoholic drinks, as we shall see, actually retards the chemical processes of digestion. The explanation given seems, according to our present knowledge, the only likely one, though evidently it is not complete.

The third class of food-accessories is an important one. The natural aroma of foods is, as we have said, appetising; this appetising action, which may affect the brain through the special senses of the eye or nose, is associated with a flow of the salivary secretion, and a corresponding flow of gastric juice. The food-accessories we are now considering have a similar stimulating action on the digestive juices when they are ingested. Small doses of alcohol, for example, increase the flow of gastric juice, and thus act as a distinct aid to digestion. Small quantities of soups and beef-tea probably act in the same way, and although there is no very definite knowledge on the subject, spices, hot flavouring agents and onions, &c., are considered to have a similar action. Schiff, indeed, affirms that it is necessary that certain substances (peptogens) should be absorbed before the gastric juice can be secreted; among such substances are dextrine and peptones. This, however, is doubtful.

Not only, however, have this class a stimulating effect on the salivary and gastric secretions, but they stimulate in many cases the muscular movements of the stomach. Alcohol and spices probably have this action. On the other hand, they have by many experiments been shown to have a powerful retarding effect on the chemical processes of digestion.

The experiments, the results of which will presently be detailed, were all performed outside the body; they were artificial digestions. A great distinction must be drawn between digestive experiments outside the body and the actual processes occurring in the stomach, which is the organ that now concerns us, inasmuch as it is the receptacle of the food. For the stomach is an organ in which not only the chemical process of digestion is progressing, but the products of digestion (peptones, &c.), the salts, and the diffusible bodies taken in with the food (such as alcohol, tea, &c.), are constantly being absorbed. When we speak, therefore, of a certain percentage of a substance hindering digestion in a test tube, it is not accurate to apply the results obtained directly to the phenomena of digestion in the stomach. But although this is so, yet valuable dietetic deductions may be drawn from the results of experiments on artificial digestion. Sir William Roberts, W. Fraser, Bikfalvi, and others have made experiments in this direction, and the conclusions arrived at have been closely similar. On the digestion of starch by the saliva, Roberts found that the distilled spirits, coffee, and cocoa had practically no effect when these substances were used in quantities which would be considered as dietetic doses. On the other hand, tea and wines of all kinds had a powerful retarding effect on the digestion of starch—an effect, in the case of tea, not due to the volatile oil, or the theine (caffeine), but probably due to the tannin. In the cases of wines, the effect was probably due to the acidity of the wines; salivary digestion is not active, as is well known, in a distinctly acid medium.

The effect of food-accessories on gastric digestion is much more important than that on salivary or pancreatic digestion. Salivary digestion is of minor importance in man, whereas the preparation and digestion of the food in the stomach are of vast importance. If gastric digestion is too much delayed, there is a liability to the occurrence of various forms of bacterial fermentation (the butyric acid fermentation, &c.), which lead to gastric disturbance and malassimilation of the food.

Roberts[1] and others have shown that in artificial gastric digestion proof spirit[2] has no appreciable effect unless it is present to the extent of 10 per cent. of the mixture. Twenty per cent. of proof spirit added to the digesting mixture causes a well-marked retardation of the fermentative process, while if 50 per cent. be added the activity of the ferment is paralysed. Proof spirit, brandy, whisky, and gin (the distilled spirits) affect gastric digestion only in proportion to the amount of alcohol they contain. If we inquire what dose of these ardent spirits is requisite to retard digestion in the stomach, we find that a much larger quantity is necessary to do this than is ordinarily taken. Thus, taking the average mass of food in the stomach as about two pounds, a dose of two ounces of average brandy would be equivalent to only 5 per cent. of proof spirit in the mixture—a proportion which does not appreciably affect the chemical process of digestion. It is also to be remembered that even this quantity of brandy does not represent 5 per cent. of proof spirit for any length of time in the stomach, for the diffusible alcohol is constantly being absorbed; larger doses of brandy than two ounces would therefore probably not affect the process of fermentation. We may therefore conclude that as food-accessories the ardent spirits (brandy, whisky, gin) have a twofold action; they stimulate the secretion of gastric juice when taken in small quantities, they retard gastric digestion when taken in intoxicating doses, dietetic doses having no effect in this direction.

The effect of wines, malt liquors, tea, coffee, &c., and beef-tea, and whey is quite different from that of the ardent spirits. To some extent, when taken in small doses, they act as stimulants to the secretion of gastric juice, but they all have a well-marked retarding effect on the chemical process of gastric digestion. In the case of wine and malt liquors, this retarding effect is not proportional to the amount of alcohol contained in them; there is something else present which is more retarding than alcohol. Of the wines, sherry and port wine have the most retarding effect. Thus 20 per cent. of the sherry which was used (equal to 8 per cent. of proof spirit) added to the digestive mixture trebled the time of normal digestion. A proportion of 40 per cent. (16 per cent. proof spirit) completely stopped digestion. These results differ from those described as due to alcohol pure and simple. As Roberts points out, the use of half a pint of sherry at dinner would make a mixture in the stomach containing 25 per cent. of the wine; a proportion which, as we have just seen, markedly retards the process of digestion. Such a habit, therefore, can only be deleterious.

Hock, claret, and champagne (containing from 10 to 12 per cent. of alcohol) have a less retarding effect than port or sherry; and champagne has a less effect than the first two wines mentioned. Twenty to 40 per cent. of the wines in the digestive mixture hinders digestion; an effect out of proportion to the alcohol they contain, which would only be present in the proportion of 2 to 4 per cent. The effect of malt liquors on peptic

[1] *Dietetics and Dyspepsia*, London, 1885.

[2] Proof spirit contains by weight 49·3 per cent. of absolute alcohol and 57·09 per cent. by volume; a 10 per cent. mixture may therefore be considered as containing approximately 5 per cent. of absolute alcohol.

digestion is more marked than that of these light wines, but is, as in their case, out of proportion to the alcohol they contain. Ten per cent of 'light English table beer' and of lager beer added to the digestive mixture did not delay digestion; but a retarding effect was noticed when 20, 40, and 60 per cent. of these liquors were added. These percentages represent only about 1, 2, and 3 per cent. of alcohol. Beer is often drunk in large quantities at meals, and Roberts considers that it must often be present in the stomach contents in the proportion of 50, 60, or even 80 per cent. Such proportions would distinctly retard the chemical process of digestion.

Tea, coffee, and cocoa all retard gastric digestion, and café noir (to the extent of 10 per cent.) was very powerful in this respect. Beef-tea retards, whey to a less extent.

The retarding effect on digestion of the food-accessories is ascribed by Sir William Roberts to the presence in the liquids of the salts of organic acids and of neutral inorganic salts—speaking more particularly to lactates and sarcolactates (in beef-tea) and to the chlorides of potassium and sodium. When salts of the organic acids (lactates, butyrates, &c.) are taken into the stomach, they are decomposed by the hydrochloric acid of the gastric juice, by which, therefore, the organic acids are set free. Gastric digestion is most active in the presence of free hydrochloric acid, and although the presence of a small proportion of free organic acids in the stomach contents does not stop digestion, it tends to hinder the activity of the pepsin. The development of these acids probably explains the retarding effect of beef-tea and whey on digestion, since hyperacidulation by means of hydrochloric acid brings the activity of the digestion almost up to the normal in the presence of these food-accessories. Hyperacidity of the digestive mixture does not counteract the retarding effect of light wines and of Burton ale on digestion; and with port or sherry it actually aggravates the retardation. The retarding effect on digestion of wines and malt liquors is not, therefore, due to organic acids, but probably in part to the neutral inorganic salts present. The question, however, is not settled.

It is interesting to note that Roberts found effervescent water to be a slight stimulant to the chemical processes of gastric digestion; a result explicable on the consideration of the evolution of bubbles of carbonic acid gas agitating the digesting mixture.

On pancreatic digestion the effect of food-accessories is interesting. Roberts found that the retarding effect of wines, beer, and tea on the pancreatic digestion of starch was due to the acidity of these beverages; if the acidity were neutralised, as it is normally in the duodenum, they had no retarding effect.

The effect of the food-accessories on the pancreatic digestion of proteids was found to be practically nil. Tea and coffee had no appreciable effect, and the digestion of milk was only slightly interfered with by 10 per cent. of proof spirit. A large percentage of alcohol is probably never present in the duodenal contents, since it is so readily absorbed from the stomach.

The general action of the food-accessories which has just been discussed is accompanied by special actions of individual food-accessories which are more appropriately discussed under each separate heading. It may be well here to discuss certain conclusions from the facts concerning the general action of food-accessories which have just been discussed.

1. As to the aroma of food and the use of so-called condiments. Those who can easily procure a sufficiency of food can also produce a variety, and there is evidence to show that a variation in the articles of diet used, although

one may be as nutritious as the other, is of great service in preserving health. The lower animals, and probably the lower races of mankind, can subsist on monotonous food; but civilised man seems to require variety. This variety includes variation in the different aromatic principles present in foods, variations in the mode of cooking, and variations in the condiments, spices, pepper, vinegar, &c., added to the food in the cooking. Such facts are important to bear in mind in connection with public institutions and bodies of men where all are supplied with the same kind of food, and where economy has to be considered.

Monotony of food, the bad cooking of food, or the non-addition of condiments (which are very cheap) may lead to disgust and refusal of food or to disordered digestion. As examples of the difference in this respect between foods of similar composition may be cited bread and biscuits: good bread is never tired of during one's lifetime; good biscuits if eaten for any length of time are refused at last. So with well-cooked fresh meat and the over-cooked tinned meat; the first is greatly superior to the latter as an article of diet.

2. We shall have to discuss the possible useful action of those food-accessories which act on the central nervous system under the separate headings of alcoholic beverages, tea, &c. One possible explanation of their utility has already been brought forward (p. 476).

3. With regard to the retarding effect on digestion of many of the food-accessories, it has been suggested by Sir William Roberts that, anomalous as it may seem, the retardation may be in many instances of actual benefit to the absorption of food. Thus in the case where large meals are eaten, with which these digestion-retarding food-accessories (soup, beer, wines) are often taken in fairly large quantities, the retardation of digestion may be of benefit in allowing the food to be more completely digested and absorbed. The length of time food remains in the stomach varies according to the quantity and kind of food, and whether the meal taken has consisted of one article of diet or is a mixed meal. This has been already discussed (p. 419). Leube,[1] experimenting on healthy persons, found that after an average meat meal the stomach was not completely empty under seven hours. This, however, is against what we know from the experiments of Beaumont and Richet. Leube's estimate is too high. It is, moreover, probable that the time of digestion of a particular meal (or rather the time in which it is expelled from the stomach) varies not only in each person, but in different bodily conditions of the same person. No exact statement on this point can thus be made. But from such a consideration it is likely that the retarding effect on digestion of food-accessories may be reduced to a minimum (e.g. in persons of very vigorous digestion) by the great rapidity of natural digestion, by increased rapidity of absorption, and by the activity of the muscular walls of the stomach. The results of experiments in test tubes on the retarding effect of food-accessories must not be too rigidly applied to particular individuals. These experiments show what might have taken place in certain, perhaps abnormal, conditions, which are perhaps more interesting to the physician than to the student of Public Health.

I. Condiments

Many food-accessories may be grouped together as 'condiments,' since they are added to food as flavouring agents. These are such as mustard, pepper, onions and vegetables allied to them, pimento, cloves, cinnamon, nutmeg, caraway, cardamoms. Vinegar and common salt are also con-

[1] *Deutsche Archiv f. klin. Med.* Bd. xxxiii. 1883.

diments. The former has already been considered (p. 473), and the uses of common salt have been frequently discussed.

The condiments now under consideration—pimento, cloves, cinnamon, &c.—owe their action as food-accessories to the aromatic oils they contain. Oil of mustard and piperin, the active principle (resin) of pepper, have an action similar to the aromatic oils. This action is manifold. The active principles are first *antiseptic* (oil of mustard is powerful in this respect), so that they serve the useful purpose when taken with a large mixed meal of tending to prevent acid fermentation in the digestive tract. They are also *stimulants of the secretion of the digestive juices*; they certainly stimulate salivary secretion, and thus reflexly (also probably directly) the secretion of gastric juice. Thirdly, they *stimulate peristaltic action*. Taken in quantity and by themselves, some of them (such as cloves and pimento) act as stimulants to the nervous system; but this is not an action associated, as a rule, with their *rôle* as food-accessories.

Pepper.—Black pepper is obtained from *Piper nigrum*; white pepper is the same decorticated. Both occur in commerce as 'seeds' and in powder, and the latter is liable to adulteration. In black pepper, free of water and of sand, the amount of piperin and fixed oil is about 7·87 per cent., and the amount of carbohydrate transformable into sugar is 49·33 per cent., not less. This quantity of carbohydrate may be taken as a test of the purity of the pepper. In white pepper, fixed oil and piperin is 8·24 per cent., and carbohydrates are 64·95 per cent., of which 46·72 per cent. are starch.

Pepper is adulterated with olive stones, spent ginger, palm-nut powder, rape seeds, and mustard husks.[1]

Mustard is the seed of the *Sinapis alba* and *Sinapis nigra*. It is sold in powder, which is liable to adulteration, being mixed with different kinds of starchy flours (such as wheaten flour, barley flour, and linseed). These adulterations are detected by the microscope (see pp. 451–454). Turmeric is also added.

Pure mustard contains 0·66 per cent. of volatile oil, 35·42 per cent. of fixed oil, and 13·95 per cent. of carbohydrates. The carbohydrates in adulterated mustard are as high as 67 per cent. sometimes, the fixed oils in such specimens being below 7 per cent.[2]

2. Food-accessories Taken as Liquids

The food-accessories taken in a liquid form may be divided into two groups: (1) the liquids containing alcohol; beer, wine, &c.; (2) the liquids containing the active principles caffeine or theobromine; such as tea, coffee, Paraguay tea, cocoa.

1. *Alcoholic Beverages*

These owe their action as food-accessories chiefly to the ethylic alcohol they contain; and the effect of the different kinds of alcoholic drinks is, broadly speaking, proportional to the amount of alcohol present, but not completely so, since the majority of alcoholic drinks owe part of their effect to the action of aromatic substances and certain other principles, which will be discussed afterwards. Although, therefore, the amount of alcohol present is important, yet the presence of these other principles must be considered also in deciding the utility or non-utility of any given alcoholic drink.

The use of alcohol to mankind dates from time immemorial; it is so readily produced from sugars and starches by fermentation that its early dis-

[1] See König, *op. cit.* Bd. i. pp. 731–735. Also Hassall's *Food and its Adulterations.*
[2] See König, *op. cit.* Bd. i. p. 739.

covery by the human race is not to be wondered at. Its use, too, in the world is so widespread that the manufacture of alcoholic drinks has become an important industry in civilised countries, and the tax on its production an important addition to the revenue of these countries. It would be out of place here to inquire whether this extended use of so powerful an agent is of benefit to the social well-being of the community. The introduction of alcoholic beverages into savage or semi-savage communities leads rapidly to the extinction of the aborigines, and to the abuse of alcohol must be ascribed a large proportion of crime and immorality. A great mortality attends the class of inebriates when they are attacked by infectious disease and by pneumonia or when they meet with severe accidents. The question, however, for consideration here is the physiological effect of alcoholic beverages, and what value they may possess in civilised communities.

Classification and Composition of Alcoholic Beverages.—For the sake of convenience, and also according to the amount of alcohol they contain, alcoholic drinks may be divided into (1) beers, (2) light wines (red, and white), (3) sweet wines (champagne, port, sherry, &c.), and (4) spirits (brandy, whisky, &c.).

1. *Percentage Composition of Beers*

—	Sp. gr.	Water	CO_2	Alcohol. Wt. per cent.	Extract	Proteid	Sugar	Dextrine	Acid (lactic)	Salts	Phosphoric acid
Lager beer .	1·0162	90·08	0·196	3·93	5·79	0·71	0·88	3·73	0·151	0·228	0·777
Bock beer .	1·0213	87·87	0·234	4·69	7·21	0·73	1·81	3·97	0·165	0·263	0·089
Ale . .	1·0141	89·42	0·201	4·73	5·65	0·61	1·07	1·81	0·278	0·310	0·086
Porter .	1·0191	88·49	0·215	4·70	6·59	0·65	2·62	3·08	0·281	0·363	0·093

The sugar and dextrine in beer render it liable to fermentation, during which free acids (acetic, &c.) are formed. The salts of beer consist of chlorides and phosphates of potassium and sodium and of calcium. Besides the alcohol, the most important principle present in beer is derived from the hops used, especially the lupulin (see PHYSIOLOGICAL ACTION OF BEER, p. 486).

2. The light wines, and the sparkling, differ slightly in the amount of

Percentage Composition of Light Wines (Red and White)

—	Sp. gr.	Alcohol. Wt. per cent.	Extract	Tartaric acid	Glycerine	Nitrogen	Tannin and colouring matter	Mineral salts	P_2O_5	H_2SO_4	KHO
Moselle	0·9964	7·99	2·24	0·79	0·72	0·031	—	0·175	0·036	0·026	0·068
Rhine wine											
White	1·0005	8·00	2·60	0·81	0·85	0·048	—	0·230	0·046	0·020	0·085
Red	0·9966	10·08	3·04	0·52	—	—	0·158	0·249	—	—	—
French wine											
Red	0·9982	7·80	2·56	0·57	0·73	0·043	0·180	0·248	0·030	0·033	0·106
White	0·9963	10·31	3·03	0·66	0·97	—	—	0·250	0·032	0·038	0·098
Lower Austrian wine											
White	0·9949	7·93	2·13	0·67	0·68	0·022	—	0·189	0·034	0·039	0·081
Red	0·9958	8·49	2·54	0·62	0·81	0·026	0·110	0·241	0·037	0·033	0·101
Hungarian wine											
Red	0·9952	9·02	2·54	0·67	0·79	0·034	0·150	0·215	0·038	0·024	0·091
White	0·9955	8·00	2·33	0·69	0·77	0·027	—	0·204	0·034	0·025	0·075
Italian wine . . .	—	10·63	3·44	0·52	1·45	0·013	—	0·290	0·032	0·019	0·115
Spanish wine											
Red	—	12·31	3·53	0·49	1·09	—	0·220	0·610	0·027	0·221	0·242

Australian wine contains from 13 to 14 per cent. of alcohol by weight, 16 to 17 per cent. by volume.

ethylic alcohol they contain, but much more in the quantity of ethers and aromatic substances present. Red and white wines are obtained from France, Germany, Austria, Hungary, Italy, and Spain, and also from Australia. The best sparkling wines (champagnes) are from France.

3. Although champagnes differ from port and sherry in their effect, yet they are best classed under the same heading as sweet wines, owing to the amount of sugar they contain.

Percentage Composition of Sweet Wines

—	Sp. gr.	Alcohol. Wt. per cent.	Extract	Tart. acid	Glycerine	Tartar	Sugar	CO_2	Mineral salts	P_2O_5	H_2SO_4	KHO
Champagnes												
Veuve Cliquot .	1·0565	10·20	19·75	0·60	1·13	0·25	17·52	0·514	0·12	0·016	0·022	—
Röderer (carte blanche) .	1·0572	9·50	20·24	0·70	0·97	0·26	18·50	1·514	0·12	0·012	0·017	—
Monopole . .	1·0280	8·21	10·15	0·57	0·23	—	8·45	0·897	0·13	0·016	0·025	0·059
						Nitrogen						
Port wine . .	1·0081	16·69	8·05	0·40	0·43	0·027	5·82	—	0·23	0·031	0·023	0·102
Sherry . . .	0·9932	17·45	3·98	0·45	0·52	0·027	2·12	—	0·38	0·031	0·128	0·206
Madeira . .	1·0003	15·40	5·52	0·43	0·74	0·020	3·23	—	0·35	0·060	0·075	0·149
Marsala . .	1·0022	15·85	5·27	0·49	0·51	0·037	3·53	—	0·38	0·029	0·114	0·142

There are other constituents of these wines which are important, but cannot be expressed in a table of percentage composition. These are chiefly the 'compound ethers,' which give the 'bouquet' to wine, although this is also partly due to other aromatic bodies present. The compound ethers are numerous, and consist mostly of œnanthic ether, but citric, malic, tartaric, acetic ethers, and the ethers of higher members of the fatty acid series are also present. The bouquet of wine is a permanent quality, as long as the wine remains sound; it is, however, developed by keeping for a greater or less length of time.

The colouring matters of wine are, to a greater or less extent, deposited on keeping, the wine thus becoming lighter in colour. All wines are acid, and this acidity is due to free tartaric acid, and to the acid tartarate of potassium (tartar); but other vegetable acids are also present. Tannin, derived from the stalks and skins of the grape, is also present, rendering new wine astringent; it is deposited on keeping the wine, entering into combination with some of the organic bodies present.

On keeping wines, therefore, the chief chemical changes that occur are the deposition of some tannin and colouring matter, the loss of a little alcohol and volatile acid.

4. *Spirits* contain the largest quantity of alcohol of all alcoholic beverages. They are made by distilling fermented grapes (brandy), fermented molasses (rum), fermented malt or malt and grain and other materials (whisky). The greater part of the whisky is distilled in 'pot-stills,' in which the fire is directly applied to the still containing the fermented liquid. 'Patent' or 'silent' spirits, which are largely used for blending potable spirits and for fortifying wines, are made by exposing a subdivided stream of the fermented liquid to steam.

According to Bence Jones and Hassall (quoted by Parkes[1]), gin contains from 49 to 60 per cent. of alcohol, with an acidity of 0·2 grain tartaric acid per ounce, and 1 per cent. of sugar. It is usually made by adding juniper

[1] *Op. cit.* p. 319. As sold, however, gin may be 35 per cent. under proof, containing usually about 30 per cent. of alcohol.

and other flavouring and sweetening agents to patent spirits. The specific gravity of brandy is 0·929 to 0·934; of gin, 0·930 to 0·944; of whisky, 0·915 to 0·920; and of rum 0·874 to 0·926.

Percentage Composition of Spirits

In 100 cubic centimetres are grammes—

—	Water	Alcohol	Extract	Acid=acetic	Salts
Common brandy	64·90	35·1	—	—	—
Cognac	55·60	43·9	0·385	0·067	0·024
Whisky[1]	47·80	52·2	0·036	0·027	—
Rum	36·50	61·4	1·975	—	0·060

The basis of spirits is ethylic alcohol mixed with water; but they also contain alcohols higher in the series than ethylic (classed together as 'fusel-oil'), compound ethers, and empyreumatic bodies produced during the process of distillation. The varying proportions of these 'bye-products' give spirits their individual characters, such as taste and aroma. In 'patent' spirits the chief higher alcohol present is propylic; in spirits made from molasses and from malt and grain, amylic and butylic alcohols are the chief alcohols present. The aroma of brandy is due to compound ethers, œnanthic, butyric, &c., and that of rum to butyric ether. One of the chief empyreumatic bodies in 'pot-still' whiskies is furfurol, which is present to the amount of 0·005 per cent.

When spirits are kept for several years they become 'mellowed.' The change is usually considered to consist in a diminution of the higher alcohols and the ethers; but J. Bell has shown that in spirits kept in bond for six years there is practically no change in the proportion of higher alcohols and ethers present, and that the 'mellowing' appears to be due to the empyreumatic bodies, including furfurol, diminishing in quantity and altering in quality so that they become less harmful.[2]

The Physiological Action of Alcohol and of Alcoholic Beverages

The physiological action of alcohol, that is, of pure ethylic alcohol, is not precisely the same as that of the alcoholic beverages which are in ordinary use. These contain other bodies besides alcohol, which possess a physiological action of their own, and one which is not always masked by the presence of ethylic alcohol. It will be well, therefore, to consider the action of alcohol first.

1. *Physiological Action of Alcohol.*—A great distinction must be drawn between the effect of alcohol taken in dietetic doses, and the effect when taken in excess. Although this is no doubt true, it is, however, difficult to lay down any general rules as to what excess of alcohol really means. It does not mean simply that alcohol is taken until it produces intoxication: that is undoubtedly excess. But there are many individuals in whom a moderate amount of alcohol, habitually taken, produces severe pathological effects. It may be said that these are weakly, although apparently healthy, individuals, and that this is a question more of medicine than of normal dietetics. It is, however, a fact of great importance to bear in mind in discussing the question of alcohol, that what is a dietetic dose for one individual may produce in another serious effects, if the habit is persisted in.

[1] Whisky is usually under this strength, and as sold may be 14 to 30 under proof.

[2] Report on British and Foreign Spirits by a Committee of the House of Commons, 1891.

The experiments of Anstie, of Parkes and Count Wollowicz showed that with strong, healthy men, 'accustomed to alcohol in moderation,' the amount of alcohol which could be taken daily without doing harm was between one and two ounces. If more than this quantity of alcohol were taken in the day, alcohol was detected in the urine; a sure sign that too much had been taken. It is not quite accurate, however, to apply these results generally. As has been noted already, owing to the idiosyncrasy of alcohol, one ounce of absolute alcohol daily to some individuals would be a poison, the effect of which would be aggravated if the amount of alcohol were translated into terms of beer, claret, or other wines. The dietetic dose which might be taken without harm by the majority of town livers is probably under one ounce. Parkes' and Wollowicz' experiments were performed, it must be recollected, on 'two powerful, healthy men accustomed to take alcohol.'

When taken into the stomach, dietetic doses of alcohol increase the vascularity of that organ, producing a sensation of warmth, and also augment the secretion of gastric juice. At the same time the appetite is excited. This is no doubt the explanation of the taking of alcohol before meals; a custom, however, strongly to be deprecated, since the form of alcohol usually taken is concentrated and liable to produce indigestion. The effect of alcohol on the chemical process of digestion has already been discussed. Roberts, Bikfalvi, and others have concluded that even when alcohol is present in the digestive mixture to the extent of 10 per cent. it has no appreciable effect on the fermentative changes occurring. It is otherwise, however, with alcoholic beverages—beer, wine, &c. (p. 475 *et seq.*).

When taken for some length of time in excess, alcohol causes a great disturbance of the digestive system. It causes loss of appetite, with a sense of craving for alcoholic drinks, and a long train of dyspeptic symptoms. Morning nausea and vomiting also appear, due to the fact that in most cases the alcohol is largely taken in the evening, and the stomach remains partly full during the hours of sleep. The prolonged use of alcohol also causes the bowels to act two, three, or four times a day, and this is a common symptom in habitual topers. To the effect of alcohol must be ascribed some cases of severe gastric catarrh and the degeneration of the secretory glands of the stomach observed by Wilson Fox. After being absorbed into the blood, alcohol, according to Schmiedeberg,[1] forms a compound with hæmoglobin, which more readily gives off oxygen than hæmoglobin itself. The result of this is that alcohol lessens oxidation in the blood and the tissues. Most of the alcohol taken is oxidised in the body, the products being excreted in the urine. In dietetic doses, some of the alcohol may be detected in the expired air, but it can be detected in the urine only when the dose is excessive. The presence of alcohol in the urine is, therefore, to some extent, a chemical test of an excess of alcohol having been taken.

Alcohol stimulates the heart, producing increased force and rapidity of the cardiac beat. It thus tends to increase the blood-pressure by acting on the heart, and to increase the flow of blood from the arteries into the veins. The effect on the blood-pressure is, however, partly counteracted by a coincident dilatation of the blood-vessels of the skin, which thus becomes flushed, and tends to produce more sensible perspiration.

It is a question whether alcohol sensibly lowers the temperature of health, and authorities are not agreed on this point. There is no doubt that in some cases of fever alcohol does lower the temperature, especially in children; and in health it may be considered to tend to lower the body-temperature in two ways, as Dr. Lauder Brunton points out, first, when given in medium doses,

[1] Quoted by Brunton, *Pharmacology*, 3rd ed. p. 767.

by dilating the cutaneous vessels, whereby more blood comes to the surface of the body, and thus more heat is lost by radiation and by means of the increased perspiration; second, when given in large doses, by lessening the processes of oxidation in the body. But, although it is doubtful whether alcohol lowers the temperature of health, there is no doubt whatever that it tends to lower the natural resistance of the body against cold. When an individual is exposed to intense cold for a long period, as in the Arctic regions, he may derive some temporary comfort and sensation of warmth from the taking of alcohol; but his power of resistance to the intense cold is lessened, and instances have been recorded where death has occurred under such conditions during sleep.

The physiological effects of alcohol which have been considered are quite subsidiary to its effect on the central nervous system, as there is no doubt that it is for this effect on the brain that alcoholic beverages are so universally taken by mankind. The first effect that alcohol has on the brain is that of a stimulant, and it probably acts as such in two ways, namely, by the increasing the circulation of blood through the brain, which is thus roused to greater vigour, and by directly stimulating the nerve-cells of the nerve-centres. This stimulant effect is observed chiefly after medium or dietetic doses. and its result is seen in many individuals by an increase of mental and bodily activity, and of acuteness of perception by the special senses. This beneficial physiological effect is, however, soon replaced by poisonous symptoms if the dietetic doses are too often repeated, or a large quantity of alcohol is taken at once. For alcohol then becomes a depressant and paralyser of the central nervous system, and symptoms of intoxication appear. This depressant effect is, as Brunton points out, one of progressive paralysis. The higher centres of the brain are first affected, then the lower. The perceptive centres are paralysed, so that correct judgment is no longer possible, while the emotions are uncontrolled and thrown out of working gear, fits of boisterous hilarity and of emotional depression being common symptoms. Speech becomes disordered, and symptoms of inco-ordination, due probably to an effect on the cerebellum, appear. The respiratory centre in the medulla then becomes affected, and at this stage there is coma with stertorous breathing, while the action of the heart still continues, even after respiration has stopped.

There can be no question that alcohol taken in sufficient quantities to depress the higher centres of the brain does an infinite amount of harm. The only question regarding the use of alcohol is whether when taken in quantities sufficient to produce its stimulant effect on the brain it is beneficial or not.

The serious symptoms and pathological changes produced by the use of alcohol in excess may be summarised as follows:—

It delays digestion, causes catarrh and degeneration of the stomach, and produces morning vomiting, looseness of the bowels; symptoms referable to the alimentary tract. It also causes congestion of the liver, and its prolonged use ends in fatty degeneration or fibrosis (cirrhosis) of that organ, with its attendant serious results. It seems doubtful whether alcohol can of itself produce a fibroid condition of the kidneys.

Acute alcoholic poisoning produces coma and a peculiar form of delirium with hallucinations terrible to the patient (delirium tremens), while to chronic alcoholic poisoning may be ascribed a particular palsy, chiefly affecting the extremities and caused by a peripheral neuritis.

The abuse of alcohol also lessens the resistive power to disease, especially acute disease; and such individuals die rapidly when affected with pneumonia and other acute affections.

2. *Physiological Action of Alcoholic Beverages.*—The physiological effect of beer, wines, spirits, &c., partly depends on the amount of alcohol they contain, and partly on other ingredients which have a physiological action of their own.

It is not always possible to say what these ingredients are chemically; but there are some facts which are known and which are important. The retarding effect of beers and wines on the chemical processes of digestion has already been considered at length, and the cause, as far as is known, of this retarding effect. It is now necessary to consider the other effect of these alcoholic beverages, as such.

Many alcoholic drinks, especially potent spirits, owe their deleterious effect to what may vaguely be described as 'impurities.' Some of these impurities consist of alcohols higher in the series than ethylic (see p. 483). Dujardin-Beaumetz and Audigé have found experimentally that such alcoholic drinks, with impurities, are more poisonous when given to animals than the purified spirits. The following table[1] of the results of these observers shows these results. Bad brandy, it will be seen, is more poisonous than absolute alcohol in the proportion of 5·3 to 7·75. The smaller the poisonous dose, the more deleterious the alcoholic beverage will be when drunk.

Poisonous Action of Different Kinds of Alcoholic Preparations

Kind of alcohol	Average poisonous dose per kilogramme of body-weight of the dog, necessary to produce death in 24–36 hours		
	Spirits and brandies	Crude	Rectified
	Grammes	Grammes	Grammes
Ethylic alcohol	7·75	—	—
Spirit of wine of Montpellier . .	7·50	—	—
,, ,, from pears	7·35	—	—
,, ,, from cider and from marc of grapes	7·30	—	—
Spirit from grain	—	6·96	7·25
,, molasses and beetroot .	—	6·90	7·15
Brandy from a public-house (ordinary quality)	7·00	—	—
Brandy from a public-house (inferior quality)	5·30	—	—
Spirit from potatoes	—	6·85	7·10
,, ,, (said to have been ten times rectified) . . .	—	—	7·35

Some of the undoubtedly deleterious effects of crude spirits must be ascribed to the presence of furfurol and other empyreumatic bodies, which diminish and alter on keeping the spirit. These substances tend to derange digestion and appear to have a profound effect on the nervous system.

Beer has an action of its own, probably dependent on the active principle (lupulin) of the hops used in its manufacture. Lupulin is a depressant to the nervous system. To many individuals, beer in small doses acts as a soporific, and in excess it has a well-marked depressant action. This depression is probably due to the lupulin, and not to the potassium salts, as considered by Ranke. Taken for prolonged periods, beer, even in dietetic doses, seems to lead to the deposition of fat in the body, and it probably produces

[1] Taken from Brunton's *Pharmacology*, 3rd ed. p. 771. See original paper of Dujardin-Beaumetz and Audigé in *Comptes Rendus*, vol. lxxxi. pp. 192–194.

this result by lessening oxidation and tissue metabolism in the body.[1] Taken in excess for long periods, beer is a 'gout-producer,' and one of the most potent dietetic agents in the causation of that disease.

In wines, both light and sweet, the constituents, besides alcohol, which are of importance are the vegetable acids and the compound ethers. Beer also contains vegetable acids and their salts, and spirits contain compound ethers; while in all these are mineral salts, which are of service in the economy. In beer and the sweet wines there is also a certain amount of carbohydrate foodstuffs in the form of sugar and dextrine. According to the amount of carbohydrate present, these alcoholic beverages, therefore, supply valuable food to the organisms; but not in an admixture, it must be remembered, in which it is necessary, or convenient, for the organism to assimilate it.

The vegetable acids, however, especially in light wines, undoubtedly play an important *rôle*; since they make the wines antiscorbutic. The compound ethers, besides aiding in giving the bouquet to wines and spirits, act on the central nervous system as sedatives, and when taken in excess, as depressants. An effect has been ascribed to them of stimulating the secretion of pancreatic juice, and in this way wines and spirits containing them would be of aid in digestion. It is true that Claude Bernard showed that sulphuric ether acted in this way; but no facts are as yet forthcoming to show that the compound ethers present in alcoholic beverages possess this beneficial action.

The Dietetic Use of Alcohol

Alcohol, it is often said, is no necessity to the healthy individual. But no hard-and-fast rule can be laid down on the subject. We have to take into consideration the surrounding physical conditions of the individual, the poverty or ease, the hard mental or bodily labour, all of which conditions may surround healthy individuals. We have also to take into consideration the colossal fact of the almost universal use of alcohol among nations, more perhaps among civilised than among savage races.

To some individuals, alcohol in every shape or form is a poison, not necessarily producing intoxication, but causing in course of time bodily degeneration, with an increase of fatty and fibroid tissue in different parts of the body.

It has already been pointed out what effects alcoholic beverages taken in dietetic doses have on the chemical processes of digestion and on the nervous system; effects which may not only not be deleterious, but be of service in the conditions of life under which we live. Thus even the retardation of digestion may be of benefit in aiding the complete assimilation of a large meal; and the stimulant action on the nervous system may restore the nervous system to a healthy condition. This last action, indeed, may, in many cases, be considered more as a question of therapeutics than of dietetics; for the condition of nervous system produced by over-work, in which alcohol in small doses with meals is often beneficial, is a pathological and not a physiological one.

There is no cogent evidence to show that alcohol is of service in increasing bodily activity. The evidence adduced by competent observers is distinctly against the use of spirits by soldiers in time of war. And when bodily exertion has to be combined with judgment in directing one's action, alcohol, by

[1] The amount of carbohydrates present in beer does not account for the deposition of fat.

blunting the judgment, may do great harm. There is no doubt, however, that alcohol is of service in conditions where there is deficiency of food; for it enables, for a short period it is true, bodily vigour to be maintained on an insufficient diet.

II. Beverages containing Alkaloids

Tea, coffee, Paraguay tea, guarana, and cocoa come under this head. The first four have as their active principle the alkaloid theine or caffeine; cocoa contains theobromine, and the effect of these beverages in their dietetic use is chiefly due to these alkaloidal principles.

Caffeine or theine is chemically trimethylxanthine or methyltheobromine, $C_8H_{10}N_4O_2$. Theine, the alkaloid from tea, is considered as identical with caffeine, and is commercially sold as caffeine. It is not, however, according to May, quite identical with caffeine in its physiological action. Caffeine exists in coffee beans in about 0·5 to 1·24 per cent., in tea from 2 to 4 per cent., and in guarana about 5 per cent., and in Paraguay tea in from 0·48 to 1·85 per cent.

In its physiological action, it plays the *rôle* of a cerebral stimulant, exciting (but not necessarily over-exciting) the brain to continued activity and stimulating muscular activity. Both coffee and tea have these physiological effects. Caffeine, moreover, stimulates respiration and increases the blood-pressure; but in its further effects (as from an overdose) it makes the pulse more frequent and in some cases intermittent. Caffeine is also a diuretic. Both tea and coffee may also have this action on the pulse and urine. The good effects of tea and coffee are evident from what has been said; they stimulate the brain and restore muscular activity.

Their evil effects are partly seen in symptoms of disorder of the digestive tract and partly in those of a disordered nervous system. Thus tea and coffee indulged in to excess produce dyspepsia, chiefly of the acid form. Their effect in delaying the chemical processes of digestion has already been discussed (p. 474 *et seq.*). The disordered digestion arising from the abuse of tea and coffee has been ascribed to the tannin present in the infusion. There is, however, no evidence of this. It is not the tannin that delays the digestion, as Roberts has shown; and most of the symptoms of tea and coffee abuse are those of delay of digestion, i.e. of food remaining undigested in the stomach. Caffeine is itself a gastro-intestinal irritant, and coffee in some individuals produces diarrhœa. It is not, however, clear what constituent of tea and coffee is the active agent in producing dyspepsia.

On the side of the nervous system coffee and tea may lead to sleeplessness and restlessness; in some people such symptoms are noticed even if the beverages are not taken to excess. Tea, moreover, may produce muscular tremor.

Some effect must be ascribed to the aromatic principles present in tea and coffee; these no doubt greatly add to their consumption or have the same physiological effect as the aromatic principles already discussed (p. 474).

Theobromine, the active principle of cocoa, is closely related to caffeine; it is dimethylxanthine, $C_7H_8N_4O_2$. Only traces of caffeine are found in cocoa.

The physiological action of theobromine is chiefly exerted on the muscular system; it is a greater restorer of muscular activity. Its effect on the nervous system is not well defined.

Cocoa in infusion has but little physiological action, owing to the small amount of theobromine present. In its raw state, cocoa is largely composed of fat and to a less extent of carbohydrates; and even in the 'prepared'

cocoas, fat is present in large amount. Cocoa must therefore be considered as a fatty food, and thus differs markedly from tea and coffee.

Tea

Tea consists of the dried leaves of *Camellia thea.* It is grown in China, India, and Ceylon, and from these countries the European supply is derived. It is also grown in Japan, the tea produced being green in colour. Black tea is the form usually employed in Europe, the use of green tea having greatly diminished. Green tea contains more theine, ethereal oil, and tannin than black tea.

The tea as sold consists of the dried leaves, which are curled; they may be uncurled by placing in hot water and unrolling, and then placing on a slip of glass. The shape is ovate and pointed, with serrated margin almost to the stalks. The length varies somewhat. In all teas stalks will be found.

The venation of the leaves is characteristic. The large veins do not reach the border of the leaf, but turn in towards the mid-rib.

Composition of Tea.—The average percentage composition of black tea is 9·51 of water, 3·58 to 4·70 of theine, 24·50 of nitrogenous substances, 0·68 of ethereal oil, 6·39 of fat, wax, chlorophyll, and resin, 6·44 of gum, dextrine, &c., 15·65 of tannin, 16·02 of pectin, 11·58 of cellulose, and 5·65 of ash (Geissler).

Wynter Blyth gives, as the average composition of black tea, 6·44 per cent. of water, 1·43 of theine, 35·61 of 'extract,' 6·75 of gum, dextrine, &c., and 6·72 of salts, of which 3·29 are soluble, 0·70 consists of silica, and 1·44 of potassium. The salts of tea consist, besides those of silicon and potassium, of sodium, magnesium, iron, and manganese, combined with phosphoric acid, chlorine, and carbonic acid.

Infusion of Tea.—All the constituents of tea are not soluble in hot water; but most of the soluble substances are dissolved in the infusion as made. In 100 parts of tea (air-dried), 33·64 parts are soluble in water, consisting of 12·38 parts of nitrogenous substances (including theine), 17·61 parts of nitrogen-free substances, 3·65 parts of salts, of which 2·10 parts consist of potassium salts.[1]

Tea infused, as it ought to be, for the period of three minutes only, does not contain so large a proportion of soluble matter.

Adulterations and Examination of Tea.—Good tea consists mostly of whole leaves of the characteristic structure previously described. Other leaves containing tannin are mixed with tea as adulterations; such as the willow, oak, sloe, hawthorn, elder, beech, and (in China) the *Camellia sasanqua* and *Chloranthus inconspicuus.* None of these, except the sloe, willow, and the *Camellia sasanqua* and *Chloranthus* could be mistaken for tea leaves. The sloe is distinguished by its obovate shape as contrasted with the ovate, acute tea leaf; the willow leaf is characterised by its irregular serration.[2]

Tea is sometimes mixed with insoluble matter, such as catechu, sand, and magnetic oxide of iron. The last two fall to the bottom of an infusion and are readily detected.

In the examination of tea, an infusion ought to be made to judge of the aroma and astringency. The aroma is slight in old or adulterated tea.

The *total soluble matters* are estimated by infusing a weighed quantity with a large excess of distilled water, and evaporated to dryness on a water-bath.

[1] This large proportion of potassium salts in the infusion may account for part of the depression following the abuse of tea.

[2] For further information on these points see Hassall, *op. cit.*

The *ash* ought not to be above 8 per cent. in air-dried tea: it is usually about 5·5 to 6 per cent.

The *amount of tannin* may be estimated by infusing a weighed quantity of tea and precipitating the tannin with gelatine: 100 parts of the dried precipitate is equal to 40 parts of tannin.[1]

Coffee

Coffee is obtained from the seeds of *Caffea arabica*, obtained from various parts of the tropics. The principal varieties are Mocha, Ceylon, and West Indian, all differing somewhat in flavour.

The compositon of unroasted coffee beans is 11·23 per cent. of water, 12·07 per cent. of nitrogenous substances, 1·21 per cent. of caffeine, 12·27 per cent. of fat, 8·55 per cent. of sugar and dextrine, 33·79 per cent. of tannin and other nitrogen-free bodies,[2] 18·17 per cent. of cellulose, and 3·92 per cent. of salts, which consist chiefly of potassium and phosphates. This is the average composition. In some specimens of coffee, the percentage of caffeine is higher, and that of cellulose may be from 27·5 to 34·4 per cent.

In the roasting of coffee, the caffeine is not destroyed, but dissociated from its combination with the tannin: the sugar and dextrine are changed into caramel, while some of the cellulose is charred, and gases of combustion are given off and water evaporated. At the same time the aroma is developed. The average composition of roasted coffee is 1·15 per cent. of water, 13·98 per cent. of nitrogenous substances, 1·24 per cent. of caffeine, 14·48 per cent. of fat, 0·66 per cent. of sugar, 45·09 per cent. of other nitrogen-free bodies, 19·89 per cent. of cellulose and 4·75 per cent. of salts.

Infusion of Roasted Coffee.—For the making of good coffee (an art practically unknown in this country) the berries must be freshly roasted and ground. The percolator used must be warmed, and one large teaspoonful of the ground coffee for each breakfast-cupful placed in it.

A sufficiency of boiling water must then be added and allowed to flow through; and after it has flowed through, it must be returned to the percolator again; twice is, as a rule, sufficient to obtain a good infusion. Boiling the infusion destroys the aroma. One hundred parts of coffee yield to boiling water 25·50 parts of soluble matter, consisting of 3·12 parts of nitrogenous substances, 5·18 parts of oil, 13·14 parts of non-nitrogenous substances, and 4·06 parts of salts.

The *physiological action* of coffee and of its active principle, caffeine, has already been discussed (p. 488).

Adulterations of Coffee.—The ground coffee is adulterated with chicory and with several starch-containing grains, the cereals, beans, maize, and potatoes, and with sugar.

The *composition* of chicory varies greatly from that of coffee. In 100 parts, there are in roasted chicory 13·16 parts of water, 6·53 of nitrogenous substances, 2·74 parts of fat, 17·89 parts of sugar, 41·42 parts of other non-nitrogenous bodies, 12·07 parts of cellulose, and 6·19 parts of salts. The large amount of sugar in roasted chicory as compared with that in roasted coffee (17·89 per cent. in the former and 0·66 per cent. in the latter) is a point of distinction, as well as the larger proportion of salts (6·19 and 4·75 per cent.)

Chicory may also be distinguished by the fact that the roasted berry sinks

[1] For the process for the separation of theine see Richter's *Organic Chemistry*, p. 349 English translation, 1886.

[2] The proportion of tannin is about 5 per cent.

in water, while the freshly roasted coffee berry floats, and by the microscopical examination which shows in chicory the dotted ducts.[1] The presence of any of the varieties of *starch* is shown by the blue colour given to a dilute infusion with solution of iodine and by a microscopical examination.

Acorns and parsnip roots are sometimes used to adulterate ground coffee.

Paraguay Tea—Guarana

Paraguay tea (*maté*) is obtained by roasting the leaves of *Ilex paraguayensis* and exposing them to the action of the sun. It is used in Paraguay and other parts of South America. It contains 3·87 per cent. of proteids, 0·48 per cent. of theine (1·48, according to Byasson), 2 to 4·5 per cent. of fat, resin, and chlorophyll, 2·38 per cent. of sugar, 4·1 per cent. of tannin, and 3·92 per cent. of salts: 24 per cent. of the solids is soluble in water.

In infusion, it has an action similar to other caffeine-containing beverages, but is more apt, it is said, to cause digestive disturbance.

Guarana is obtained by roasting the seeds of *Paullinia sorbilis*. It contains a large proportion of caffeine, 5 per cent. It has been used in migraine with some success.

Cocoa

Cocoa is prepared from the seeds of the *Theobroma cacao*. Cocoa beans consist of 7·11 per cent. of water, 0·45 per cent of theobromine, 51·78 per cent. of fat, 8·33 per cent. of starch, and 3·60 per cent. of salts. When charred and burnt, some of the starch becomes changed into dextrine and sugar. The beans then have the following composition: 5·58 per cent. of water, 14·13 per cent. of nitrogenous substances, 1·55 per cent. of theobromine, 50·09 per cent. of fat, 8·77 per cent. of starch, 13·91 per cent. of other nitrogen-free bodies, 3·93 per cent. of cellulose, and 3·45 per cent. of salts.

The cocoa found in commerce is 'prepared:' a part of the fat is removed, and in most cases starch and sugar are added. An average composition of such preparations is the following:—6·35 per cent. of water, 21·50 per cent. of nitrogenous substances, chiefly proteid, 1·82 per cent. of theobromine, 27·34 per cent. of fat, 2·53 per cent. of sugar, 15·17 per cent. of starch, 16·48 per cent. of the non-nitrogenous bodies, 5·44 per cent. of cellulose, and 5·19 per cent. of salts.

Cocoa is, therefore, a fatty and a proteid food, and to some extent a carbohydrate food also. It has but little stimulant action, but the small amount of theobromine present no doubt acts as a restorer of muscular activity. The cocoa of commerce is largely adulterated with the different starches of the cereals, potato, arrowroot, &c., the presence of which is readily detected by the microscope. Sugar is also added. Mineral adulterations are detected by chemical tests.

[1] For further information on this point see Hassall, *op. cit.*

THE INSPECTION OF MEAT

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THE INSPECTION OF MEAT

The Legislature imposes important duties and powers upon the duly appointed officials of sanitary authorities in respect to the examination of meat. The Acts in which these duties and powers are defined are sections 116, 117, 118, and 119 of the Public Health Act and the Sale of Food and Drugs Act. In the great majority of instances action is taken under the first-named Act, but occasions sometimes arise when it becomes necessary to proceed under the latter Act: for example, in the fraudulent substitution of the flesh of one animal for that of another.[1] Section 6 of the Sale of Food and Drugs Act provides that 'no person shall sell to the prejudice of the purchaser any article of food which is not of the nature, substance, and quality demanded by such purchaser, under a penalty not exceeding twenty pounds.' It is important to bear in mind that in proceeding under this Act all its requirements must be carefully observed: the article must be *purchased* by the officer or his agent, and must be submitted to the analyst,[2] whose certificate specifying the result of the analysis must be produced in court; moreover, the person purchasing the article must, on the completion of the purchase, forthwith notify to the seller his intention to have the article analysed by the public analyst, and offer to divide it into three parts to be then and there separated and sealed up, one to be delivered to the seller (if he so wish), one to be given to the analyst, and one to be retained for future comparison. A person refusing to sell any article to any officer is liable to a penalty of 10*l.*

The ordinary procedure under the above-named sections of the Public Health Act is different from the foregoing. Section 116 of this Act directs that 'any medical officer of health or inspector of nuisances may at all reasonable times inspect and examine any animal, carcase, meat, &c., exposed for sale or deposited in any place for the purpose of sale, or of preparation for sale, and intended for the food of man, the proof that the same was not exposed or deposited for any such purpose, or was not intended for the food of man, resting with the party charged; and if any such animal, carcase, meat, &c., appears to such medical officer or inspector to be diseased, or unsound, or unwholesome, or unfit for the food of man, he may seize and carry away the same himself or by an assistant, in order to have the same dealt with by a justice.' It is not necessary for the officer to give notice to the owner of the goods seized, but it is customary to do so if the owner can be found.

Section 117 says that 'if it appears to the justice that any animal, carcase, meat, &c., so seized is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall condemn the same, and order it to be destroyed or so disposed of as to prevent it from being exposed for sale or used for the food of man; and the person to whom the same belongs or did belong at the

[1] An importer of large quantities of tinned meat was recently convicted and fined at the Liverpool Police Court for selling tins labelled 'Superior Roast Mutton,' which contained beef with mutton fat poured over it; the difference in price per 2-lb. tin between the beef and mutton was threepence.

[2] Omission to do this has resulted in the dismissal of a summons.

time of exposure for sale, or in whose possession or on whose premises the same was found, shall be liable to a penalty not exceeding 20*l.* for each piece, or at the discretion of the justice, without the infliction of a fine, to imprisonment for a term of not more than three months.'

It is a question whether it is a necessary requirement that the justice should himself inspect the article; in some places this is done, but in others the justice does not himself inspect, but adjudicates upon these cases as he does upon others, viz., upon the evidence brought before him. The late Mr. Raffles, stipendiary magistrate of the City of Liverpool, whose experience was probably unique, would never inspect meat, declining, as he said, to act both as judge and witness. Another sound reason why the fitness or unfitness of meat for food should be decided upon the evidence of those practically acquainted with the details of the question, rather than by the personal inspection of the justice, is the admitted necessity of special knowledge to enable a correct opinion to be arrived at in the matter.

By section 118 of the same Act a penalty is imposed for hindering or obstructing an officer, and section 119 empowers a justice to grant a warrant to an officer to enter any premises, to search the same, and to seize any article therein which he may deem unsound, unwholesome, or unfit for the food of man, in order that it may be dealt with in the manner described.

Characteristics of Sound Meat.—Good meat is firm and elastic to the touch, not pitting or crackling on pressure; juicy, but not wet; the fat, when sufficient time has elapsed for the carcase to cool and set, is firm, the suet hard—containing no jelly or watery juice—is free from blood stains, and in colour varies from creamy white to deep yellow; the pleura and peritoneum are free from adhesions or staining. The flesh should be that of a well-nourished animal—not attenuated; the colour should be uniform, without brown or discoloured patches. Good beef is of a bright colour, marbled with fat; the flesh of the calf is always paler and less firm to the touch; mutton is a dullish red, firm, the fat hard, usually white, but a marked yellowness is consistent with wholesome meat. The flesh of the pig is pale, and less firm to the touch; the fat also is soft; the carcase should be plump, the skin smooth, not setting in folds or wrinkles. In all cases, special attention should be paid to the connective tissue about the flanks and shoulders and diaphragm, and below the fat of the kidneys; wetness, œdema, tubercle, or other evidences of disease may be found here; the thoracic and abdominal parietes should be examined for evidence of stripping, staining, or other abnormal condition; the odour of the carcase should be sweet, and a skewer plunged into the flesh should have no unpleasant smell on withdrawal.

The age of animals is important. Young animals are recognised by the condition of the bones and their cartilages; with advancing age, ossification becomes more complete, the bones are firmer and more compact, while the cartilage diminishes. Newly-born, or still-born calves have a watery appearance of flesh; the fat is tallowy, and the hoofs are yellow, readily indented with the nail, and show that the animal has not walked on them. In old animals the proportion of fat to lean lessens; bull-beef is firmer and coarser than ox-beef, darker in colour and less juicy; in the heifer the udder is not fully developed, and contains much fatty tissue; in the old cow which has had several calves it is loose, spongy, and brownish in colour; the fat of the old cow is deficient, and the flesh coarser in texture and darker than that of the heifer, whilst the bones are completely ossified.

Wherever possible, the viscera should be examined, and a knowledge of human pathological processes will always stand the medical officer in good stead; when examining carcases the general features of sound meat must be carefully

borne in mind, and due weight given to the aggregate deviations from the normal standard. It may be laid down as a broad general rule, that *in all chronic wasting diseases* there is emaciation, often to an extreme degree; the flesh is pallid in appearance and, together with the connective tissue, may be infiltrated with serum; the fat and visceral connective tissue are also wet and flabby, and the fat will not set; occasionally the pleura is found to have been stripped off from the ribs to remove evidence of pulmonary disease. In *acute inflammatory diseases* the affected organ will present the ordinary signs of inflammation, but if the animal be slaughtered at an early stage of the disease, and is properly bled and dressed, the flesh is usually normal and sound; if, however, the animal has not been killed until when moribund, or if the disease has made progress, the carcase will be found to be red and congested from imperfect bleeding; it will not set properly, and the flesh will be dark, dry, and sticky, and frequently giving off an unwholesome odour of drugs which can be best detected by plunging a skewer deeply into the flesh and observing the smell.

The appearance of the carcase is dependent to a considerable extent upon the manner in which it is dressed; a butcher who is a good hand at his trade, and who is clean, careful and prompt in killing and dressing cattle, will secure a better wholesale price than an indifferent man. In all cases the dressing should be completely finished before the carcase sets; on no account should the intestines remain in longer than is necessary. In dressing cattle, when the animal has been bled, the hide is partially removed from the abdomen and hind quarters, and the animal is then hauled up by the hind limbs and disembowelled; the hide is then carefully removed from the carcase, so as to leave the fat on the back as smooth as possible. The carcase is then split with saw and cleaver, the divided brisket being bent back on either side and secured with hooks over the flat ribs, in order that when set the part shall be thicker and more convenient for sale. Care is taken to keep the meat clean, in order to lessen or prevent the necessity for washing.

In dressing sheep, the skin is partially removed immediately the animal is bled; the carcase is then suspended by the hind extremities, disembowelled, and the skin entirely removed; a stick, the extremities of which are fixed in the abdominal walls, is passed across the back of the animal, so as to expose the inside of the sheep. The fore-limbs are not allowed to set in the drooping position they naturally assume, but are fastened up with skewers so as to set in the thickened and contracted shape most convenient for sale, and which is familiar to everyone.

Lambs are treated in the same manner, but in the early part of the season the skin is not entirely removed, in order that the flesh may not become dry; the feet also are left on. In dressing lambs, a piece of omental fat is spread out on each hind quarter, and a piece of mesenteric fat, carefully removed from the intestines, is sold with each fore-quarter.

Calves are dressed in a similar fashion to lambs. Pigs, after being bled, are scalded, scraped, and disembowelled in the manner already referred to; they set with a smooth and plump surface.

All ill-dressed carcases should attract attention, since diseased animals, or those killed when moribund, are frequently dressed hurriedly and by unskilled hands, and present a slovenly appearance. At the same time, it must be mentioned that in some parts of the kingdom cattle are always ill-dressed, frequently packed whilst warm, and despatched to market; these are not attractive in appearance, but may be perfectly sound.

Refrigerated Meat is imported into this country in immense quantities, and usually in prime condition, and it keeps well on exposure. Beef is im-

ported in quarters, wrapped in muslin cloths; the fat is sometimes stained with the meat juice, which gives it a dullish red appearance; carcases of sheep are imported entire, usually wrapped in muslin cloths. When commencing to thaw, both beef and mutton become wet on the surface, and if again placed in the refrigerator, and afterwards again thawed, present a wet and unsightly appearance which must not be confounded with œdema, since the flesh is sweet and good, notwithstanding its appearance.

Some important conditions affecting the flesh of animals used for food have to be considered. Among *parasitic diseases*, the most important affecting the sheep is occasioned by the presence in the liver of the *Distoma hepaticum*, commonly known as the fluke. The parasite in question is somewhat sole-shaped, about ½ inch to 1 inch in length, and is found in the bile-ducts in very varying numbers. A few of these creatures may be met with in otherwise perfectly sound sheep, and exercise no prejudicial effect whatever upon the flesh, but as their numbers increase, important structural changes take place from pressure and obstruction to the flow of bile; jaundice and dropsical swellings set in, together with diarrhœa and falling off of the hair; emaciation is rapid, and so extreme, as to give rise to the common name of the 'rot' which butchers apply to the disease. The affected liver should in all cases be destroyed, and the carcase should be condemned if it be deteriorated. The disease is met with in all parts of the country, but more especially in damp and wet localities, and during the long-continued prevalence of wet weather; the eggs and the embryo are developed in water, and hence wet seasons are conducive to the spread of the disease.

Cœnurus cerebralis, the cystic form of the *Tænia cœnurus* of the dog, is met with in the brain of the sheep and ox, producing the disease known as 'turnsick,' 'sturdy,' or 'gid.' In the early stages no material effect is produced upon the flesh, but with the advance of cerebral symptoms the animal emaciates, the flesh deteriorates, and becomes ultimately in-nutritious and valueless as an article of food. In all cases the parasite should be destroyed.

The *Strongylus filaria* are liable to be met with in the lungs of the sheep, and ultimately produce wasting of the tissues.

Parasitic animal organisms, by which the human being may be attacked, are of great importance. Two of these may reach him through the medium of the flesh of the pig.

The *Tæniadæ* pass through two distinct phases in two different hosts: the encysted state of the *Tænia solium* of man constitutes the *Cysticercus cellulosæ* which commonly affects the pig, in which it gives rise to the disease known as 'measles.' The 'measly' pork contains the *cysticerci* in greater or less abundance, lodged chiefly in the muscular tissues, voluntary or involuntary, also in the liver, brain, connective tissues, and serous membranes; they are not met with in the fat. The parasite in this stage consists of the scolex and its cystic surrounding; the cyst averages the size of a pea, and is embedded between the muscular fibres, from which it can be readily removed and the crown of hooklets demonstrated. The parasite is difficult or impossible to detect during the life of the animal, but the cysts are readily visible as soon as the animal is killed and opened; calcareous degeneration of the cysts sometimes takes place, a condition which is readily noticeable. In every case of this affection, the carcase of the animal should be condemned and destroyed; it is both prudent and desirable to treat hams and bacon in which the condition may be found in a similar manner, notwithstanding that the processes of curing and cooking may destroy the parasite.

Trichina spiralis is a still more formidable parasite, and gives rise to the

disease known as trichinosis. The parasite attacks other animals besides the pig, but the occurrence of trichinosis in man is usually due to the consumption of the flesh of an infected pig, commonly, it is believed, in an imperfectly cooked state. The trichina are small thread-like worms, coiled in minute ovoid cysts within the muscular fibres: each cyst contains one immature trichina, which is liberated when the capsule is dissolved by the processes of digestion; the liberated trichinæ develop rapidly: the female is amazingly prolific, ova are formed and impregnated, and the young find their way into all parts of the body of the host. They are found in the greatest extent in the voluntary muscles, but have also been met with in the fat; the diaphragm and inter-costal muscles are said to be favourite sites.

Careful examination is necessary for the detection of the trichinæ: close inspection reveals a speckled appearance, but thin sections of the pork should be immersed for a few minutes in liquor potassæ, until the muscle becomes translucent, washed, and afterwards examined with a lens or low power of the microscope, when the coiled-up worm will be seen; the cysts are occasionally gritty from the presence of carbonate of calcium.

All the flesh of an infected animal should be destroyed.

Dr. Carsten describes as follows the energetic measures adopted in the Netherlands in connection with an outbreak of trichinosis, and which resulted in the complete extinction of the disease :—'A Royal decree was issued prohibiting the removal of pigs and pig manure from an infected district, and a special veterinary inspector was stationed temporarily in the neighbourhood as supervisor; the local authorities instituted a strict search for trichinæ, ordering that all pork before consumption be submitted for inspection to a competent committee appointed for that purpose; that all pig-yards be overhauled, and that wherever any trace of trichinæ be found, the infected swine, and all vermin found in the neighbourhood thereof be killed, and, together with the offal, consumed by fire.' [1] These measures proved quite effectual.

Tuberculosis.—Cattle, pigs, poultry, and rarely sheep, are all liable to be affected with tubercle, but it is in cattle, and more especially milk-cows, that tuberculosis is met with. The flesh of the tuberculous animal is affected in varying degrees, and much diversity of opinion exists as to the stage at which the flesh should be condemned. Opinion is practically unanimous that in advanced stages of tuberculosis the consumption of the flesh should be prohibited, not that every observer is prepared to state that its consumption would give rise to specific inoculation, but on the general grounds that the flesh is so deteriorated as to possess no longer the nature, quality, and properties of wholesome nutritious meat. Thus far the position is a simple one, and any practical butcher can recognise when the disease has advanced so far as to prejudice the quality of the meat.

Tuberculosis is known by various names, such as 'grapes,' 'wasting,' 'pearls,' and the like, the first term being perhaps the commonest, from the fancied grape-like arrangement of the nodular tuberculous masses frequently found adhering to the chest-walls. The most common seats of the disease are the lungs, pleuræ, and other serous membranes; the liver, lymphatic, and other glands are often affected, sometimes the marrow and the nervous system, and it is also alleged that bacilli have been found in the flesh. The extent of the local lesions varies widely; they may be limited to a single nodule, or almost the entire organs mentioned may be invaded, their tissues destroyed by caseous or calcareous masses or by liquefying pultaceous matter. Grape-like aggregations of various sizes attached to serous membranes are

[1] Communicated to the Seventh International Congress of Hygiene and Demography.

extremely common, and the condition left by stripping them away with the costal pleuræ with a view to conceal the appearances of disease, should at once attract attention and lead to a close examination.

The various conditions are all forms of one and the same process, and caused by a microbe which, growing in the tissues, gives rise to the tubercles, and which, by reason of its being thrown off from the diseased animal in quantity, renders the malady a contagious one. The temperature which is most favourable to the growth of the microbe is that of the ordinary body-heat of a warm-blooded animal, say 98° to 100° Fahr. A temperature of or below 32° Fahr. appears to kill it, as does also continued exposure above 108° Fahr. These are points of considerable practical moment, as suggestive of the probable effects of cooking or of refrigeration upon the bacillus. It is regarded as established that the infectious discharges of a tubercular animal remain actively virulent in this climate for a long time after they have been cast from the body, and stalls and sheds may thus become a source of danger unless thoroughly cleansed. Inhalation appears to be the usual way in which the microbe enters the body, a circumstance which would be anticipated from the frequency with which the lungs are the seat of the disease; on introduction into the blood, the disease may spread so rapidly as to constitute acute or general tuberculosis, or, on the other hand, it may be limited for a considerable time to the point of entry and neighbouring lymphatic glands, which local lesions are frequently the only ones detectable, producing during life no symptom whatever, the animal being slaughtered in prime condition.

As the malady progresses, emaciation and weakness become marked, milk diminishes and is poor in quality; when the animal is slaughtered the extensive signs of the disease already described are met with, the flesh is soft, skinny, and dropsical, the fat wet and flabby, the carcase, in short, presenting every sign of unsound meat.

A very important and much discussed question is: At what stage is the flesh of a tubercular animal unfit for human consumption? Some observers contend that the whole carcase should be destroyed if the merest trace of tubercle is discovered, even though the carcase may be otherwise in prime condition. The general practice, however, in this country is to condemn any carcase in which the disease is extensive, or has progressed so far as to cause deterioration of the flesh. In Prussia, where very great care is taken in inspecting meat, the law is to this effect:—'The condition of the flesh of a tubercular animal is to be regarded as dangerous to health when the meat contains tubercular nodules, or the tubercular animal has begun to show emaciation; while, on the other hand, the meat is to be regarded as fit for food when the masses of the tubercle only occur in an organ, and in general the beast is well nourished.' The French decree says: 'The flesh of tuberculous animals shall be excluded from consumption (1) if the lesions are generalised, that is to say, not confined; (2) if the lesions, although localised, have invaded the greater part of an organ, or constitute an eruption on the walls of the chest or the abdominal cavity.'

That the tubercle bacillus may be introduced into the body by swallowing is shown by the fact that tubercular secretions, mucus, saliva, portions of tubercles from diseased tissues, and cultures of the bacilli have been swallowed by various animals, and some of these animals have subsequently developed the disease. It will be noted that in all of those cases the presence of the bacilli was demonstrable in the tissues swallowed—the most diseased parts were, in fact, carefully selected for the experiments. There is obviously a vast difference between eating masses of tuberculous matter, and eating the properly cooked flesh of an animal which is sound except for the presence

of, say, a nodule in the lung. In the report of the inquiry of the Departmental Commission appointed by the Privy Council in 1888 to inquire into the subject of tuberculosis, no case of tuberculosis in man from eating the flesh of tubercular animals was stated, although witnesses were fully interrogated upon this point. Professor Bang, of Copenhagen, thinks that experiments show that the muscular tissue is so unfavourable a nidus for the tubercle bacilli that they do not multiply in it. He is of opinion that the seizure of the meat of every tuberculous animal is too severe a measure, and where the lesion is localised he does not consider that the consumption of the meat is attended with danger.

Foot and Mouth Disease is common amongst cattle, sheep, and pigs. It is characterised by rise of temperature as a premonitory symptom, the animal showing by sucking its lips and the movements of its tongue that the mouth is the seat of suffering; saliva flows freely from the mouth. On examination, vesicles, or their bases ulcerated from maceration in saliva, are found on the tongue and on the mucous membrane of the mouth. The animal does not refuse food, but frequently drops it instead of swallowing it, feeding being evidently attended with pain. In most instances the feet are also affected, blisters forming around the hoofs ultimately drying into scabs; vesicles also frequently form upon the udders of milk cows, more especially about the teats, which dry after a time into scabs. The disease is very infectious, but as a rule so mild in its course as to interfere but slightly if at all with the condition of the flesh of animals affected by it. Occasionally in chronic cases, or when the infected animals have been exposed to wet or neglect, the conditions may be aggravated, the eruption extending into the alimentary canal, and the flesh becomes proportionately deteriorated, sometimes to an extent which renders it unfit for food. Under ordinary circumstances the flesh cannot be distinguished from that of perfectly healthy animals, and there is no reason why it should not be passed for food; the affected parts, however, the head, feet, and udder, should be destroyed.

Pleuro-pneumonia, that is, contagious pleuro-pneumonia of cattle, is a disease of great importance. The commencement of an attack is very insidious, and great difficulty may be experienced in determining the nature of the illness at the outset. The temperature soon rises to 104° or 105° Fahr., and the animal refuses food; a short dry cough develops, and the breathing becomes laboured and painful. Percussion on the side of the chest may reveal dulness, and pressure may cause the animal to shrink. In milk cows the secretion of milk is lessened or stopped. *Post mortem* the signs of inflammation of the lungs and pleura are met with; the pleural surfaces of the lungs and thorax are thickened and roughened with deposited lymph; the lungs in the early stage exhibit commencing solidification, and later, marked hepatisation, the organ being to a more or less extent solid, and necessarily greatly increased in weight; pleuritic effusion is common. The extent to which the carcase is prejudiced in respect to its fitness for human food, will depend upon the degree to which the disease has advanced before the animal is slaughtered. In the early stages nothing can be detected in the carcase to indicate that the animal had serious and acute illness; the flesh is perfectly normal in colour, smell, and consistence, and is firm and well-set; but with the advance of the disease, in addition to wasting, the flesh is dark and discoloured, imperfectly bled and badly set, moist, and the connective tissue sometimes infiltrated with serum. It is a general practice, from which there is no reason to depart, to allow carcases of animals affected with pleuro-pneumonia to pass into the market, provided they present no signs of disease,

nor departure from normal conditions; but when the disease has advanced, and the consequences already alluded to are present, the carcase should be condemned.

The legislature provides stringent regulations for the suppression of pleuro-pneumonia; immediate notification to the local authority of the existence of the disease is required, and all infected animals, as well as all others which have been in contact with those infected, are slaughtered, and compensation is paid to the owners in these cases. The infected places must be subsequently cleansed and disinfected as prescribed, and the premises are not to be declared free from infection for fifty-six days from the date of the cessation therein of the disease.

Anthrax and Anthracic Diseases.—Anthrax occurs in cattle, sheep, horses, and sometimes in pigs; the disease is rapidly fatal, especially so in cattle, the first sign of an outbreak of anthrax or splenic fever being often the discovery of a dead animal, which but a few hours previously had been in apparent health. The disease is readily inoculable into other animals, inoculative contagion being a common means of its transmission. Anthrax is of importance both on account of the devastation sometimes caused by it amongst animals which furnish food for man, and not less on account of the serious consequences which it produces in the human subject. The *Bacillus anthracis*, found mainly in the blood and spleen of infected animals, is rod-shaped, multiplying by division, and when artificially cultivated, growing into long homogeneous-looking filaments, straight or twisted, in which spores ultimately make their appearance. These spores become free, and when artificially cultivated, or injected into the blood of a rodent, germinate into the characteristic bacilli. In the human subject anthrax occurs amongst those engaged in handling raw hides, and also as 'woolsorters' disease;' the usual mode of infection in these cases is by inhalation of spores adhering to the wool of animals dead of anthrax, or by their inoculation into abrasions upon those handling hides. In all cases, in animals as in man, the blood-vessels of all organs contain the bacilli, and extravasations of blood are frequent in many parts of the body; the liver, kidneys, and spleen are congested, the spleen being much enlarged, soft, dark in colour, and sometimes found to be ruptured; this condition of the spleen gives rise to the names 'splenic fever' and 'splenic apoplexy;' the lymphatic and mesenteric glands are also enlarged and softened. In the earliest stage of disease, the flesh may not present marked change, but the local lesions rapidly develop, the odour of the flesh is of a peculiar unwholesome kind, and decomposition sets in rapidly. The flesh should be destroyed. Immediate notice of the existence of this disease must be given to the local authority, whose duty it is to ensure that measures, including cleansing and disinfection, be taken to prevent its spread, and who must order the disposal of the infected carcases by burial or destruction. 'Black-quarter,' 'black-leg,' or 'quarter-ill' is an anthracoid disease which is characterised by hæmorrhagic effusion into the subcutaneous or intermuscular tissues of one or both of the anterior or posterior extremities. The disease is not uncommon amongst cattle, is very infectious, and usually ends fatally the second or third day after infection. The extravasations, as also the abdominal and thoracic viscera, contain characteristic bacilli. The flesh of an infected animal should not be consumed even if slaughtered in the earliest stage of illness; if the disease has made any progress the carcase must obviously be destroyed; decomposition is rapid.

'*Braxy*' is a term applied to a variety of conditions, some of which are allied to splenic apoplexy in the sheep, others result from various chronic illnesses and the mal-nutrition caused thereby. 'Wet braxy' appears to

include various dropsical conditions irrespective of the cause which gives rise to them; under the term 'red braxy' appear to be included a variety of inflammatory and parturient conditions varying greatly in importance and resulting generally in discolouration of the flesh. Errors in dieting influence the colour of the flesh, occasionally giving it a dark or bile-stained appearance; but this condition may usually be distinguished from more serious inflammatory or septicæmic conditions by the degree, and by the condition of the carcase after time has been allowed for setting, and also by the absence or presence of local lesions, which must be carefully looked for. Under no circumstances should the flesh of an animal infected with anthrax or septicæmia be allowed to pass into the market, and it is almost unnecessary to say that the carcases of animals dead or killed when dying of parturient or other inflammatory diseases should also be excluded; the discoloured, stained, unbled carcase, probably in an incipient stage of decomposition, stands self-condemned, and needs no expert knowledge to condemn it.

'Joint-ill' or 'joint felon' are names applied to acute rheumatism with exudation into the joints, and also to a septic condition in very young animals, arising from septic inflammation of the navel, which gives rise to serous or purulent accumulations in the joints, and to the formation of abscesses in the neighbourhood of the affected joints; the carcases of animals so affected are totally unfit for human food.

Swine Fever, called also 'hog cholera,' 'typhoid fever of swine,' 'purples,' 'soldier,' &c., is a very fatal disease amongst swine, and one which in the later, if not in all stages renders the flesh of the affected animal unfit for consumption. The disease is readily communicable, and once it obtains a hold amongst a herd of swine the spread is rapid and the losses consequently great. Hence the stringency of the Privy Council Orders in requiring a notification of every outbreak of the disease to be made forthwith to the appropriate authority, and empowering the local authority to treat the place as an infected place, and to cause any affected swine to be slaughtered and also any swine which may have been in the same sty or shed, or in contact with the affected animals.[1]

Unfortunately, in the early period of its development, the disease during life is very difficult of detection, the animal perhaps feeding less readily, and being less vigorous than usual, but in no other way showing any important departure from the healthy state. In the varying modes of its development and progress it shows an analogy with typhoid fever in man. Sooner or later, however, more marked constitutional symptoms arise; refusal of food; rise of temperature to about 105° Fahr.; unsteady gait; partial paralysis of one or both hind quarters; diarrhœa, the evacuations being frequently mixed with blood; red patches or blotches appear on the skin, and frequently vesicles which dry up, forming a crust. In some instances extravasated patches appear. It must be noted that swine are very prone to redness of the skin, which therefore must not be looked upon as pathognomonic; exposure, over-driving, and certain articles of food, may all induce a superficial redness more or less marked.

Post-mortem examination shows inflammation and ulcerations of the alimentary canal, most commonly in the large intestine; the ulcers bear a resemblance to those of the human intestine in typhoid fever; occasionally a diphtheritic deposit covers considerable tracts of the mucous membrane of the intestine. Patches of congestion or consolidation are nearly always

[1] The local authorities are empowered to pay compensation for animals so slaughtered to the extent of half the value (not exceeding forty shillings) of a diseased pig, and full value (not to exceed 4*l.*) for a healthy pig.

found in the lungs, and the liver, lymphatics, and other parts are frequently congested or present infiltrations of blood. With regard to the carcase, it must be noted that the redness of the skin, when it exists in this disease, is apparent after scalding and scraping; the redness extends through the subcutaneous fat down to the flesh. As the disease advances, the flesh becomes emaciated to varying degrees, pale, flaccid, dropsical, and of a peculiar and unwholesome odour.

Flesh from Animals which have Died, or which have been Damaged or Killed by Accident.—The carcases of animals which have been drowned or smothered, or which have been found dead from other causes, are dark and discoloured by reason of not having been bled; the thoracic, and more especially the abdominal walls, are stained from contact with viscera, the odour is offensive, and discolouration from incipient decomposition, which rapidly advances, adds to the unsightliness of the carcase. Most meat of this class must always be condemned. Fractures, wounds, and bruising, the frequent result from animals being trampled on by others, owing to improper penning in transit, may cause injuries so extensive as to necessitate immediate slaughter; in these cases, if the animal be properly bled and dressed, the undamaged portions are normal in condition and may be passed, the damaged parts only being condemned. *Cæteris paribus*, in these animals, as in those which have been in ill-health from any cause, decomposition of the flesh appears to set in earlier than in the flesh of animals slaughtered in prime condition. It is also said that, during warm weather, Transatlantic cattle slaughtered at depôts in this country present signs of decomposition in the neighbourhood of the thigh and shoulder soon after slaughter; this is attributed to the fatigue and constant movement during the long journey.

Parturient Animals.—Carcases of animals which, owing to abnormal conditions, have been slaughtered immediately before, during, or after parturition, are not necessarily to be condemned. If the labour have been prolonged, the animal exhausted, and bruising and evidences of extravasation or inflammation about the pelvic outlet, haunch, and thighs be present, the flesh elsewhere being pale or livid, wet, and ill-set, the seizure should be made. If, however, the casualty be one such as hæmorrhage or mal-presentation, and the animal be slaughtered and promptly bled and dressed, the flesh may present no abnormal characteristic and be perfectly fit for consumption.

In *Milk-fever* the stage of the illness will influence the condition of the flesh; it should not be passed if the usual signs of deterioration are present.

Blown Veal and Lamb.—The practice—and a very disgusting one it is—exists among some low-class butchers of blowing up, with the breath, the connective tissue of veal and lamb, and thereby giving an appearance of plumpness to poor meat: the fraud is completed by taking melted fat into the mouth and blowing it over the freshly dressed carcase. The practice is an offence against ordinary bye-laws, and may be recognised by the emphysematous condition of the meat which has been subjected to it.

Consequences of the Ingestion of Unsound Meat.—It has already been pointed out that specifically harmful consequences do not necessarily follow from the ingestion of in-nutritious flesh. Meat from emaciated and worn-out animals is condemned on the sufficient grounds that it *is* in-nutritious, and in consequence has not the qualities which the consumer requires. But in regard to the consumption of flesh which is decomposing, or which is taken from animals which have suffered from inflammatory disease, or certain parasitic diseases, the consequences are very different, and few medical men have not from time to time had abundance of evidence to show this; moreover, cooking cannot be relied on to prevent this mischief. Unsound meat is

liable to give rise to symptoms of gastro-intestinal disturbance, diarrhœa, vomiting, colic, followed by more serious symptoms of septic poisoning, prostration, pyrexia, and failure of the heart's action; many such cases, some resulting fatally, have been recorded. Pies of beef or pork, sausages, and the like have also given rise to these conditions. Dr. Ballard quotes a number of cases in which mischievous or fatal results have followed the ingestion of animal food; out of fourteen such instances, pig-meat of one kind or another occasioned the illness in no less than nine, veal in one, beef in one, the kind of meat not specified in two, tinned salmon in one. An explanation is suggested of this special liability of pig-meat to produce these specific maladies: of all adult flesh meats ordinarily eaten, pork, under the process of cooking, furnishes the largest proportion of gelatin; young meats, such as veal, are also largely productive of gelatin, and gelatin is a favourite nutriment of morbific bacilli. As a result of his investigations Dr. Ballard considers that 'in infected food capable of producing disease on being eaten, we find one or both of two things—a living microscopic organism and an organic chemical poison of greater or less virulence. Of these two things, that which is immediately operative in the production of the morbid phenomena is the chemical poison which is apparently of a basic nature and a product of the processes of bacterial life.'

'Specifically different bacteria, capable of producing this chemical poison, may through its agency give rise in the human system and in animals to clinical phenomena and pathological changes in the organs which are so similar that at present they cannot be distinguished.'

'Given the bacterium and favourable environment, the bacterium may grow, multiply, and produce its own special chemical poison from the material which affords it nourishment either outside the body or within it.'

The presence or absence of an incubation period prior to the manifestation of toxic symptoms is explained by Dr. Ballard as evidence of the symptoms being due either to the operation within the body of the bacterium itself, or of their being due to the operation of the chemical poison already prepared in the food. Where merely the bacterium is introduced, time is required for its growth and for the formation of its poisonous chemical product; when the chemical poison already prepared outside the body is introduced, its operation is more speedy.

Not only is thorough cooking of importance in all cases, but equally so is the observance of absolute cleanliness in every stage of the preparation of the food for the table.

It must not be forgotten that thorough practical training is requisite before the inspection of meat can be satisfactorily undertaken. A medical man, or a veterinary surgeon, will necessarily have as a basis an acquaintance with pathological processes, and any practical butcher must necessarily have acquired experience of a useful kind. The routine work of meat inspection is in many towns relegated to an ordinary sanitary inspector, who is instructed to refer in matters of doubt to the medical officer of health. In many instances this inspector has had no special training whatever, and consequently the value of his services is small. The custom in vogue in Liverpool for many years past is to select the meat inspectors with great care; they are men physically fit, of unquestionable character, and with practical experience as butchers acquired in the public abattoirs, and are required to give proof of a thorough acquaintance with meat of all classes before undertaking the duties of inspector. Men of this class must, of course, receive an adequate wage; the work discharged by them is of great importance, and the employment of untrained and incompetent men can only result in harm.

CLOTHING

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CLOTHING

Clothing is used for the protection and adornment of the body; and although the latter object may be looked upon as subsidiary and unimportant, it cannot be neglected while human nature is what it is.

Clothing protects the body against cold and heat, wind and rain, and to a certain extent against knocks and bruises which are common enough in the daily life of most of us, but especially of the working classes. Civilised man, who is obliged to wear artificial clothing from his cradle upwards, is in this respect at a disadvantage when compared with the lower animals, whose natural clothing of fur, or wool, or hair, or feathers, is provided for them.

The power which man has, however, of changing his clothing and adapting it to differences of season and climate enables him to dwell in any part of the world, and his command of clothing thus gives him, so to say, an extraordinary power of acclimatisation.

While the uses of clothing are undoubted, it has certain inseparable drawbacks, the chief of which is the weight which it obliges us to carry; and this fact, as well as the form of our garments, must to a certain extent hamper the free movement of the body, and in some degree interfere with its development. It is during infancy and early life that attention to the hygiene of clothing is of most importance. Clothing, again, harbours dirt, and dirt is a great cause of disease, so that unless we pay constant attention to the cleansing of our clothes, skin diseases, parasitic and otherwise, are sure to result.

A treatise on clothing must necessarily be adapted to the climate and habits of the people for whom it is written, and in what follows the needs of English people, inhabiting a temperate though most variable and fickle climate, will be mainly held in view.

In dealing with the subject of clothing, we shall first of all pass in review the various materials which are chiefly used for the manufacture of clothes.

We shall next deal with the principles which should guide us in the selection of clothing, and finally we shall discuss the details of clothing, and endeavour to show how the principles previously discussed may be best applied to the clothing of the different regions of the body.

The materials used for clothing are mainly derived from the animal and vegetable kingdoms, minerals being employed only to a very limited extent for the production of the various accessories of clothing.

The materials derived from the vegetable kingdom are cotton, linen, flax, hemp, straw, jute, coir, rhea, and some other fibres of less common use, and also gutta-percha and india-rubber.

From the animal kingdom we derive furs, skins, leather, feathers, silk, and wool.

The inorganic bodies employed in the manufacture of clothing are iron, steel, and brass; glass for buttons, &c.; the precious metals, especially for the decoration of military uniforms; and, to a very limited extent, asbestos.

Wool is a modification of hair, and is furnished by the sheep, alpaca,

Angora goat (mohair), the Cashmere goat, camel, and other animals. Fibres of wool (see Plate VI. D) have upon their surface imbricated scales which all run in one direction, so that a fibre is easily pulled through the fingers from root to point, but not so easily in the opposite direction. These imbrications cause woollen fibres to adhere tightly, and make it difficult to unravel closely woven woollen textiles. 'Under the influence of moisture and pressure, tangled masses of wool thoroughly interlock and mat together by the mutual clutching of the serrations of the fibres, and it is thus that the shrinking and thickening of woollen textures under washing is accounted for, and the capacity of the cloth for felting or fulling is due to this condition of the fibre' (Paton). The serrations are most numerous, acute, pointed, and distinct in fine merino wools, as many as 2,800 per inch being counted in specimens of the finest Saxony wools. In the Leicester wool of England the serrations are less pronounced, and number only about 1,800 to the inch, so that the fibre is smoother and less waved. In some inferior wools the serrations are not so many as 500 to the inch. A similar difference exists in the fineness of the fibre, which varies from $\frac{1}{1800}$ inch in Saxony wool to $\frac{1}{275}$ in coarse Algerian wools.

By various manufacturing processes wool assumes very different aspects: cloth, flannel, blanket, worsted fabrics, knitted fabrics, are familiar examples. Felt is made without spinning or weaving, simply by the cohesion of the imbricated fibres.

'Shoddy' is made from woollen rags, which are first torn asunder by a machine called a 'devil,' and then re-spun and re-woven, with a certain admixture of fresh wool. Shoddy has not the wearing properties of new wool, but is useful for linings, rugs, wraps, druggets, blankets, &c.

Wool, according to Parkes, is soluble in a strong solution of liquor potassæ or liquor sodæ, while vegetable fibres are not attacked. It is little altered by lying in sulphuric acid, it is tinged yellow by nitric and picric acids, and is scarcely acted upon by an ammoniacal solution of cupric hydrate (cuprammonia) or by a hot concentrated solution of zinc chloride, which dissolves silk.

Wool is more porous and more hygroscopic than vegetable fabrics, and is a slightly less perfect conductor of heat. While it absorbs moisture readily, it gives it off slowly, so that far less cold is produced by the evaporation from a woollen garment than from one made of vegetable fibre. It conserves the heat of the body, and protects it from the heat of the sun, the latter property being at its height if the garment be white.

Silk (see Plate VI. C), is a fibre produced by the *Bombyx Mori* or mulberry silk moth. According to Chinese tradition, the introduction of the silk industry was due to an empress who lived more than 2,000 years B.C. It was not until the alter days of the Roman empire that silk fabrics were employed in Europe, and for a long period it remained the rarest and costliest of the textiles. The silk glands, one on each side of the body, of the silkworm open on the under lip of the larva by a common orifice. The secretion of the gland is a sticky fluid which hardens on exposure to the air.

Each cocoon furnishes on an average about 500 yards of reliable silk. According to Mr. James Paton, silk fibre consists of a centre or core of fibroin, with a covering of sericin or silk albumen, and a little waxy and colouring matter. Fibroin is analogous to horn and hair, and its composition is represented by the formula $C_{15}H_{23}N_5O_6$. It is insoluble in water, alcohol, and ether, but dissolves freely in concentrated alkaline solutions, mineral acids, strong acetic acid, and ammonical solution of cupric hydrate. Sericin, the gummy covering of the fibre, dissolves readily in hot soapy solutions and in hot water. Silk is very hygroscopic, taking up as much as 30 per cent.

of water without feeling damp. It is a perfect non-conductor of electricity. 'Silk is readily distinguished from wool and other animal fibres by the action of an alkaline solution of oxide of lead, which darkens wool owing to the presence of sulphur, but does not affect silk. Silk dissolves freely in common nitric acid, which wool does not. From vegetable fibres silk is readily distinguished by the bright yellow colour given by picric acid. Microscopically also the fibres are distinguishable. Manufactured silk is of two kinds, reeled silk and spun silk, the latter being made from the waste and spoiled cocoons by a process of carding and spinning. The gloss of the best silk is produced by a process of scouring by means of which the external albuminous coating is removed and the raw silk loses some 25 per cent. of its weight. Mr. Paton (art. Silk, 'Encyclopædia Brit.' 9th ed.) states that in order to obviate this loss it has been the practice to dye dark-coloured silks without scouring them, such silks being known as 'souples.' Silk absorbs certain metallic salts with readiness, and more readily before than after scouring. 'Up to 1857 the utmost the dyer could add was "weight for weight," but an accidental discovery in that year put dyers into the way of using tin salts in "weighting," with the result that they can now add 40 oz. per pound to scoured silks, 120 oz. to "souples," and as much as 150 oz. to spun silks, and yet call these compounds "silk." Not only so, but the use of tin salts, especially stannic chloride ($SnCl_4$), enables dyers to weight all colours the same as black.' In his 'Report on English Silk Industry' to the Royal Commission on Technical Instruction (1885), Mr. Thomas Wardle, of Leek, says:—'The proto- and per-salts of iron as well as the proto- and per-salts of tin, including also a large variety of tannin, sumac, divi-divi, chestnut, valonia, the acacias from which are obtained cutch and gambier, &c., are no longer used solely as mordants or tinctorial matters, but mainly to serve the object of converting the silk into a greatly expanded fibre, consisting of a conglomeration of more or less of these substances. Sugar is also largely employed to weight silk.'

When, therefore, we speak of 'silk' as an article employed in the manufacture of clothing, the word is used in a conventional sense only, since from the foregoing it appears that a silk garment may contain as little as 10 per cent. of true silk.

Fur.—The warmest variety of clothing is undoubtedly fur, which has been used from time immemorial by northern nations. Fur is furnished by certain animals inhabiting cold countries, which have in addition to their long 'overhair' a dense hairy covering which is called fur. A skin with the fur attached forms the best conceivable protection against cold and wind. Furs are not only prized as affording a maximum of protection to the body, but they are also in great demand for personal adornment. Ermine, chinchilla, bear, seal, and marten (Russian sable) are amongst the most valued for the latter purpose, and fetch very high prices, although for the true purposes of clothing they are in no way superior to many of the commoner and cheaper varieties of fur. (For microscopic appearance of Rabbit fur see Plate VI. H.)

Fur is also used for making felt, the hair being removed from the skin and by a process of compression, combined with heat and moisture, welded into a compact and cohesive felt owing to the entanglement of the hair by means of the microscopic imbrications on its exterior. The felts used for clothing (mainly head-coverings) are made largely from hare skins and rabbit skins. Coarser felts used for carpets, &c., are mostly made from cow hair. Felt is a fabric of great antiquity, and it is considered probable that a knowledge of felting wool preceded a knowledge of spinning and weaving.

Leather is the form in which the skins of animals are generally used for the purposes of clothing. By tanning and allied processes skins are made tough, to some extent impermeable, supple, and not liable to putrefy. The skins of many animals are used, but those of oxen are most important, the skins of horses, goats, sheep, and other animals taking a secondary place. Skins are prepared by tanning, tawing, or shamoying.

Tanning consists in steeping the skin in infusions of oak bark or other bodies containing tannic acid. By this process the gelatin of the hide forms an insoluble compound with the tannic acid, and this insoluble compound is the basis of leather. Oak bark imparts firmness and solidity to leather, and the high quality of English sole leather is said to be due to the superiority of the English oak for tanning purposes. Mimosa bark, hemlock bark (the bark of the *Abies canadensis*), catechu, and other bodies are also largely used for tanning.

To make the best quality of sole leather nearly a year is necessary, and although many modern inventions have been used for shortening the process the results in no case have been entirely satisfactory, and there now seems to be no doubt that a slowly operating process produces the best leather.

Lighter leathers, which are used for the uppers of boots, are finished by the currier, who removes inequalities from the hides, impregnates them with grease, 'grains' the surface, and finally coats them with oil, lamp-black, and tallow.

The process of *tawing* is that of impregnating skins with mineral astringents, such as alum, and it is applied to many light leathers, such as to kid uppers of boots. Recently this process has been applied to heavier leathers, bichromate of potash being the chemical employed. It is said that by this process light skins can be prepared in less than a week, ox and buffalo hides in a fortnight, and the thickest hides, such as walrus, in a month. The process is both quick and cheap, but an experienced bootmaker has informed the writer that skins prepared in this way are not fitted for high-class goods, as the leather is apt to become stiff and harsh; and this same practical authority is of opinion that nothing can replace time in the preparation of good leather.

Shamoying is employed for light skins only, and consists in impregnating the skin with fish oil, which undergoes a process of oxidation within the pores of the skin, the result being the well-known shamoy (chamois) leather, which is not unfrequently used for under-garments.

The chemical basis of *vegetable* fibre used for textile purposes is *cellulose*, to which chemists have assigned the empirical formula of $C_6H_{10}O_5$, and the percentage composition of which is (according to F. Schulze)

C	44·0
H	6·4
O	49·6

Nearly all cellulose contains a certain proportion of mineral constituents (from 0·1 to 0·2 per cent.), so that when vegetable textiles are burnt, the ash retains the original form of the fabric. There is also from 7 to 9 per cent. of hygroscopic moisture, the mean variation of which, according to the state of the atmosphere, amounts to about 1 per cent.

Cellulose is little acted upon by most solvents. The best solvent for cellulose is cuprammonia. According to Mr. C. F. Cross, the writer on 'Cellulose' in Watts's 'Dictionary of Chemistry,' the best method of effecting this solution is to place the material with some copper turnings in a tube which is narrowed below and provided with a stopcock. Strong ammonia

is poured upon the contents of the tube, and after standing for some minutes is drawn off and returned to the tube; the operation is several times repeated, until the solution of the substance is effected. 'The property of cellulose of being dissolved by cuprammonia receives an important technical application. A sheet of paper left for a short time in contact with the cuprammonia, so that the constituent fibres are superficially attacked, and then passed between rollers and dried, becomes impervious to water, and its cohesion is not affected at the boiling heat.'

The reagent which is chiefly used for the detection of cellulose, a reagent which is applicable to microscopic work, is a mixture of zinc chloride, and iodine thus prepared. Zinc is dissolved to saturation in hydrochloric acid, and the solution evaporated to the sp. gr. 2·0; to ninety parts of this solution are added six parts of potassium iodide in ten parts of water, and in this solution iodine is dissolved to saturation. By this reagent cellulose is coloured instantly a deep blue or violet.

Cotton, which is by far the most important of all vegetable fibres used for textile purposes, is the downy hair attached to the seeds of plants belonging to the genus Gossypium of the natural order Malvaceæ. Cotton garments were in use among the inhabitants of China and India at a date prior to the Christian era, and the Mexicans and Peruvians were found to possess cotton textiles in the sixteenth century.

It was not till 1770 that the planters of the Southern States of America turned their attention to cotton, and it is said that the first bales of American cotton came to Liverpool shortly before that date, and remained many months unsold.

The fruit of the cotton tree consists of a capsule containing from three to five valves, and as many divisions, holding a number of seeds. These seeds are each surrounded by a flock of cotton, which becomes swollen when the seed reaches maturity and the valves consequently open. The cotton and the seeds are pulled off, and after drying in the sun are separated from each other by the process of 'ginning.'

The quality of the cotton is judged by the length of its fibres, which vary from half an inch to an inch in length. Cotton filaments when fully ripe, but not dried, exhibit under the microscope a membranous, hollow, cylindrical tube, closed at both ends. When dried it becomes flattened and twisted, and assumes a ribbon-like shape, rather thicker at the edges than in the middle. (See Plate VI. B.)

Cotton consists mainly of cellulose, but there is also in cotton yarn, according to Dr. Schunk, about ·3 per cent. of organic matter, consisting of (1) cotton wax, (2) margaric acid, (3) a colouring matter easily soluble in alcohol, (4) a colouring matter soluble with difficulty in alcohol, (5) pectic acid, (6) albuminous matter.

In the course of manufacture cotton goods are subjected to a great variety of processes. After the weaving comes the bleaching, and then the 'finishing' of goods for the market. Among the finishing processes are mangling, starching, damping, 'beetling'—which is, in fact, hammering by machinery—and calendering, which consists of polishing by means of a machine which has been evolved from the mangle.

On the subject of 'starching' Mr. J. Paton, whose valuable articles in the 'Encyclopædia Britannica' we have frequent occasion to quote, says:—'It is in this stage that so much is done by some bleachers to give cloth a factitious appearance of weight and bulk by filling up the interstices between the fibres with compounds which have no other object than to please or deceive the eye, and some of which have a decidedly deleterious influence on the

tissues they are intended to improve in appearance. A great variety of mixtures, both cheap and nasty, are used by some finishers in place of starch with a view to produce weight and appearance; but, naturally, as little information as possible on this point is permitted to leak out to the public.'

Pure starch is alone used by reputable bleachers, but why even this is necessary it is not quite clear to one who is only a purchaser and not a manufacturer of calicoes. The same writer, in his article on calico printing, has some instructive remarks concerning the use of aniline colours, which he says 'now constitute the largest and most important section of steam-fixed dyeing materials.' . . . 'The process of fixing these colours now generally adopted is known as the arsenite of alumina process. In this process the dye is dissolved in water or acetic acid, carefully filtered through a fine cloth and mixed with acetate of alumina, a thickener, and arsenious acid dissolved in glycerine. This mixture is printed on the cloth, which is then introduced into the steaming chest. In the steaming, acetic acid is liberated and arsenite of alumina formed, which with the aniline colour is precipitated in the fibres as a brilliant insoluble lake.'

From this it appears that aniline colours in respect of their toxic potentialities may be in no respect superior to those in which compounds of arsenic have avowedly been used.

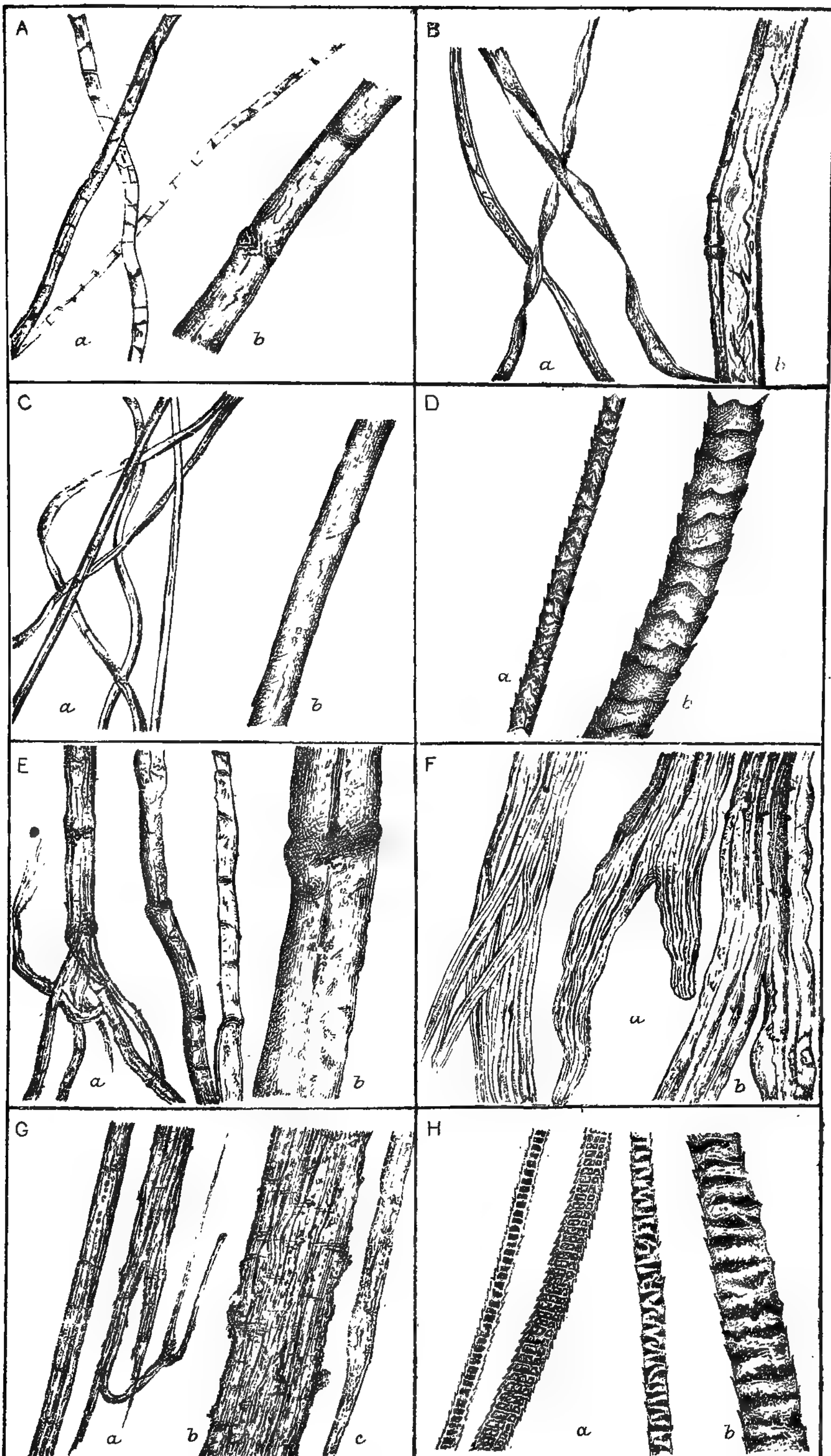
Flax has been from the earliest periods of the world's history one of the most important of the textile fibres. There is evidence that it was in use by the Swiss lake dwellers, and, coming down to historic times, there is no doubt that it was extensively employed for clothing by the Egyptians. This fibre is obtained from the stalks of *Linum usitatissimum* and other varieties of the flax plant. The plants when approaching ripeness are pulled up by the roots and the seed capsules or 'bolls' are separated, the processes being technically known as 'pulling and rippling.' The rippled stalks are then tied in bundles and, being steeped in water, are exposed on the grass to the dew, and undergo a process of putrefactive fermentation technically known as 'retting,' or 'rotting,' whereby the gummy and other matters are separated from the fibres. Finally the fibre is prepared for the market by being beaten and combed in the process known as 'scutching.' The plants yield about 6 per cent. of marketable fibre.

Hugo Müller gives the composition of best Belgian flax as follows:—

Ash	0·70
Water	8·65
Extractive	3·65
Fat and wax	2·39
Cellulose	82·57
Intercellular substance and pectose bodies	2·74
Total	100·70

Microscopically the flax fibre is seen to be marked at regular intervals by transverse striæ, which indicate the divisions of the cells of which the fibre is composed. According to Wiesner, the width of the fibre varies from ·012 to ·025 millimetre, and the length of the individual cells varies from two to four millimetres, while the fibre as a whole ranges in length from 20 to 140 centimetres. (See Plate VI. A.)

Mr. James Paton, in his article on linen in the 'Encyclopædia Britannica' says that linen is much smoother and more lustrous than cotton cloth; and, presenting a less 'woolly' surface, it does not soil so readily, nor absorb, nor retain moisture so freely, as the more spongy cotton; and it is at once a cool, clean, and healthful material for bed-sheeting and clothing. Bleached linen,



West Newman imp.

starched and dressed, possesses that unequalled purity, gloss, and smoothness which make it alone the material suitable for shirt fronts, collars, and wristbands; and the gossamer delicacy, yet strength, of the thread it may be spun into fits it for the fine lace-making to which it is devoted. Flax is a heavier material than cotton, but weight for weight it is much stronger, single yarn having proportionate strength in the ratio of 3 to 1·83, double yarn 3 to 2·26, and cloth 3 to 2·13.

Rhea is a fibre obtained from one or more species of Böhmeria, plants resembling nettles, and of the same natural order (Urticaceæ), growing in India, China, and elsewhere in tropical and sub-tropical districts. As far as the writer is aware, it has not been used for clothing, but it is likely that modern and improved methods of preparation may render it available for that purpose, and therefore it is included in this article.

Jute is a fibre obtained from *Corchorus capsularis* and *Corchorus olitorius* plants, of the natural order Tiliaceæ, which are grown for manufacturing purposes, mainly in Bengal. Jute fibre is brittle and very hygroscopic (see Plate VI. G). It is used mainly for coarse textiles, such as sacking, mats, &c. In India it is used to a limited extent for the manufacture of clothing, and in this country it is said to be employed for the adulteration of other textiles, such as silk, and also in the manufacture of false hair.

Hemp, the fibre obtained from *Cannabis sativa*, is mentioned by Herodotus as being used by the Scythians for the manufacture of their garments (see Plate VI. E).

Coir is a coarse fibre obtained from the outer husk of the cocoa-nut. It is much used for mats, ropes, and coarse work, but its use for clothing is extremely limited (see Plate VI. F).

India-rubber, or caoutchouc, is an article of clothing of great and growing importance, although of comparatively modern introduction. It is elastic and absolutely impermeable to water. The former property is of service in various accessories of clothing, such as the 'side-springs' of boots, while the latter is made use of in the manufacture of the great bulk of waterproof clothing. The first use of india-rubber for waterproofing clothes seems to have been made by the Spaniards in Mexico in the beginning of the sixteenth century, but its extensive use dates only from the beginning of the present century. Caoutchouc is obtained from the milky juice of several plants growing in Asia, Africa, and South America. Among the plants which yield caoutchouc are the *Hevea braziliensis* and the *Manihot Glaziovii*, two Euphorbiaceous trees growing in South America, and the *Ficus elastica*, an East Indian plant growing in Assam and elsewhere in the Himalayan district. The plants named, however, are only three out of several which yield this valuable product. Caoutchouc has its elasticity impaired and destroyed by a freezing temperature, and it undergoes a contraction at temperatures a little above blood heat, while at still higher temperatures it softens and melts. Caoutchouc is a complex body; it is porous and absorbs water (i.e. in its raw state) when submitted to prolonged soaking. Among its peculiar properties is the one that freshly cut surfaces unite firmly—a fact of which the chemist and the manufacturer make abundant use. Among the solvents of caoutchouc are benzene, carbon disulphide, petroleum, ether, and chloroform. Most fatty substances destroy caoutchouc, making it first soft and then hard and brittle, and to this fact is due the frequent damage done to water-pillows, &c., in hospitals. 'Vulcanisation' is effected by steeping the caoutchouc in melted sulphur, maintained at a temperature of 140° C., and by other methods. Macintosh cloth is made by spreading on layer after layer of caoutchouc paste in solution on a cotton or silk textile, but into the details of manufacture it

is not our province to enter. For most of the above facts the writer is indebted to an article by Messrs. Holmes and Bolas in the 'Encyclopædia Britannica' (9th edition).

Gutta-percha is of secondary importance as an article of clothing, as its use in this direction is almost limited to the occasional manufacture of boot soles. This material, like india-rubber, is furnished by the lacticiferous vessels of certain trees, and the distribution of these trees is almost limited to the Malay Peninsula, and to about six degrees north and south of the Equator. Seeing that the trees in order to produce gutta-percha have to be felled, and that the artificial cultivation of the tree is not practised, there is some reason to fear that this article may become scarce.

Inorganic bodies are of very limited use for clothing, now that plate and chain armour are no longer worn. The metals are, however, much used for the indispensable accessories such as hooks-and-eyes, buttons, nails and tacks. Metal springs are perhaps too much used in the manufacture of women's corsets.

Asbestos is occasionally used for making fire-proof gloves, and it is said that quite fine textiles may be made of it, and that the ancients used to wrap their dead in asbestos cloth. It cannot fairly be regarded as an article used for clothing. The same may be said of 'spun glass,' which may still be seen occasionally decorating the head of a State coachman. Mineral and other matters are abundantly used as adulterants for fabrics, in order to give weight and a fictitious amount of substance, and there is reason to think that this is much practised in the production of corduroy, moleskin, and similar heavy materials worn by the labouring classes. In the Parkes Museum is a piece of Manchester 'goods,' which after drying at 212° F. weighed 608 grains. After washing and again drying this fabric weighed 387 grains, showing that 221 grains, or more than 36 per cent. of soluble and other material removable by washing, was contained in it.

The remarks which we have incidentally made while discussing the fabrics *seriatim* will have shown that the purchaser is very liable to be deceived as to quality. At the Army Clothing Factory in Pimlico, every precaution is taken to prevent fraud on the part of manufacturers.

When fabrics arrive in the bale or piece they are first of all weighed and measured by a machine which performs both operations simultaneously and with great rapidity. In this way assurance is obtained that length and weight bear a proper proportion to each other, and that the fabric, whatever it may be, is of the desired stoutness.

The next process is called 'perching.' The fabric is unfolded, and passing over a roller near the ceiling descends towards the floor. This is done in front of a large window, so that the 'right side' of the fabric has a strong light upon it. Two scrutineers stand in front of the descending fabric, between it and the window, while a third stands behind the fabric and watches it by the transmitted light of the window. In this way flaws and blemishes are at once detected, and for every such flaw or blemish deductions are made from the contract price. Next the tearing strain is tested by a machine, which records the number of pounds of tension which causes the fabric to tear, the tearing strain being fixed by contract. The next step is to ascertain that no fibre has been used in the manufacture other than the one contracted for, and this is done by a systematic chemical analysis and microscopic examination. Finally, the dyes used are chemically examined. In this way all forms of deception are guarded against.

A thoroughly experienced eye is a tolerably safe guide for testing fabrics. Such an eye will usually detect any mixture of fibres, and will be able to judge of the quality and fineness of the weaving. It is said that good materials

have always a firm, strong selvage, and careful housewives generally look to this point. A good test is to rub the fabric briskly between the hands and against the light. A heavily sized and starched fabric will emit a cloud of dust under this test, and this cloud shows that it is very nearly worthless. Such fabrics appear far more translucent after such rubbing than they did before, and it will generally be found that these sized articles tear very readily, and after their first washing their real flimsiness is abundantly apparent.

If large quantities of a material are going to be used, it would always be wise to obtain a sample and thoroughly examine and wash it before purchasing. In this way its genuineness and the 'fastness' of the colours may be very fairly judged of. If a few fibres be teazed out and examined by the microscope, one may obtain almost absolute knowledge as to the composition of the fabric.

A great deal has been written of late years as to the best material for clothing, and there are not wanting those who urge that the 'natural clothing' of animals is the 'natural' and only proper clothing for the first of all animals—man. An assertion of this kind seems to us to be in some degree similar to the old dogma that 'animal heat' was different from other kinds of heat; a plausible theory which the hatching of eggs in incubators by means of artificial heat has done much to explode.

There can be no doubt that wool and furred skins are of great and undoubted value as articles of clothing, and that they will be eagerly sought in the future as they have been in the past. To assert, however, that these are the only proper articles from which to manufacture clothing must tend to deprive the public unnecessarily of the numerous vegetable fibres, which if properly manufactured are scarcely inferior for many purposes to garments made of wool.

The great value set upon wool as an article of clothing is attributable to the alleged fact that it has far less conducting power for heat than either cotton or linen. Thus Parkes ('Practical Hygiene,' 5th edition) quotes the experiments of Coulier and Hammond on the conducting power of different materials. 'In both cases a polished metallic vessel was filled with hot water of a known temperature, a delicate thermometer inserted, and the vessel was hung in an empty room; the time required for cooling to a given point when the vessel was uncovered and covered by different fabrics was noted by the observer at a distance with a magnifying glass.' Coulier's experiments gave the following results:—

Time required for Cooling from 122° *F. to* 104° *F.*

Vessel uncovered	18′ 12″
Vessel covered with cotton shirting	11′ 30″
" " " linings	11′ 15″
" " hemp "	11′ 25″
" " blue woollen cloth for uniforms	14′ 45″
" " red " "	14′ 50″
" " blue " great-coats	15′ 5″

It scarcely needs an experiment to show that a material used for a great-coat is a worse conductor of heat than a piece of thin shirting or lining, and that is all that the above experiment seems to us to show.

To test the thermal conductivity of different substances is a most difficult matter, and the experiments need to be conducted with a degree of precision and delicacy which can scarcely be overestimated. Whether a great-coat or a shirt conducts the better is not the question, and can never be a serious question. What we have to determine is the difference, if any, between the

thermal conductivities of equal fibres of wool, cotton, hemp, or linen under exactly equal conditions. The table of 'Thermal Conductivities' given by Sir William Thomson in his article 'Heat' in the 'Encyclopædia Britannica' (9th edition) seems to show that the difference between different fibres used for clothing is scarcely appreciable.

Copper, according to this table, is the best conductor, its conductivity being represented by the number ·91. Iron is nearly six times less than copper, its conductivity being represented by the number ·16.

The numbers given for the clothing materials are so small that they may be regarded as practically non-conductors. They are :—

Wool (carded) of all densities	·000122
Calico (new) of all densities	·000139
Hempen cloth (new)	·000144
Air	·000049
Water	·002
Cork	·000029
Eider-down	·000108

Air is one of the worst conductors of heat, and it is highly probable that the power of different clothing materials in keeping the body warm depends more upon the amount of air entangled, so to say, in the fabric than upon the material used in the construction of the fabric. That different materials are habitually woven in different ways is well known, and the fact that one material is 'warmer' than another is often due to the fact that it lends itself by its nature to a particular mode of manufacture. Woollen materials are always more porous than linen fabrics, and it is mainly to this fact that the one is 'warmer' than the other. Anything which keeps the same layer of air in constant contact with the body is warm, and when the atmosphere, though cold, is perfectly still, a thin flannel garment, or even a few layers of the thinnest gauze, is sufficient to keep the body warm. Anyone who has wrapped a newspaper round his legs in default of a railway rug has convinced himself of this fact.

Nothing chills the body more than wind, and it is when we get wind and cold combined that thick clothing becomes necessary. In some of the high Alpine valleys, where the sun is powerful and there is an absence of wind, it is surprising to see how comparatively lightly the inhabitants are clad, notwithstanding that the thermometer in the shade is down to zero. When, however, the wind gets up, warm thick clothing and furs become necessary. To resist wind, clothing must be thick, or the layers of thin clothing must be multiplied. Wind not only tends to renew the air in contact with the body, but it also quickens evaporation from the surface of the clothes, which evaporation is in itself a great cause of the chilling of the body. The best garments for resisting cold and wind are skins, with the woolly side nearest the skin. Next to skins come thick shaggy woollen clothes, such as the Scotch tweeds and Irish friezes, and the thick great-coats made of 'shoddy' which are worn by our poorer classes. After these come closely woven cloths. Impermeable materials are amongst the warmest known, because they are absolutely wind-proof, but they allow moisture to collect on the surface of the body, and as the material is, from its absolute want of porosity, a comparatively good conductor of heat, and as the accumulated perspiration is also a good conductor, the body is very liable to get chilled if they be worn continuously. 'Macintosh' clothing is of undoubted and great value for certain purposes, especially for coachmen, with whom the exposure is great and the tendency to perspiration small. They are very dangerous garments for use during active exercise.

The Chinese clothing is often in many layers, each layer being in cut and form almost precisely like its fellow, and by diminishing or increasing the various layers they are accustomed to meet the vicissitudes of their climate. This is a sound principle, and one which we may often adopt with advantage. It is recorded that Charles I. on the day of his execution, which was bitterly cold, put on two linen shirts in order that he might not shiver; an act which might have been attributed by the populace to fear.

The porosity of woollen fabrics constitutes the chief but not the only claim to their deserved popularity. It is possible, however, to imitate this quality of wool by weaving linen or cotton in a loose porous fashion, these fabrics then becoming, as heat-retainers, scarcely inferior to wool. Such fabrics are now abundantly made, but we do not deem it our duty to bring to the notice of the reader the wares of any particular tradesman.

The hygroscopic or absorbent power of the material for water is a very important matter. It is commonly asserted that the hygroscopic qualities of wool are far greater than those of the other fibres. Silk, as we have seen, is powerfully hygroscopic, as also is jute, while cellulose, the basis of all vegetable fibres, usually contains from 8 to 10 per cent. of hygroscopic moisture. There can be no doubt that as a broad rule woollen fabrics absorb or sop up far more moisture than cotton. This is partly due to the form in which the manufactured article is woven. If we compare flannel with calico, the absorbing power is most marked in the flannel, but if we compare some very closely woven and fine woollen fabric with a piece of cotton bath-towelling, the absorbent power may be perhaps greatest in the latter. It is a question how far fabrics made of vegetable fibre may be made to equal woollen fabrics in their power of absorption. A fabric which is really hygroscopic will absorb a great deal of water without feeling wet, and this power is to be distinguished from the power of merely holding water in the interstices of the fibres. Common experience is probably sufficient to prove that wool is far more hygroscopic than vegetable fibres, but these latter are certainly more hygroscopic than generally is allowed. Flannel absorbs moisture readily, and owing to its high hygroscopic power evaporation from its surface is slow. When, therefore, a man sweats in a woollen garment the garment does not get wet *through*, and the evaporation being gradual the chilling of the body when exercise ceases is comparatively slight. When a man sweats in an ordinary close-woven linen or cotton garment, the garment gets wet through and adheres to the skin, and the evaporation being rapid the chilling of the surface is great, the body being, in fact, covered with an 'evaporating lotion.' This latter evil may undoubtedly be to some extent counteracted by a looser method of weaving the material.

For work in a climate like ours flannel is the safest material to wear, or if cotton or linen be worn it must be loose-woven, so as to give some thickness and porosity to the fabric.

In tropical countries flannel is too heavy a material, and linen or cotton shirting is very generally worn, and great discomfort is experienced by its getting soaked and adhering to the skin. This trouble has been met by the Chinese, who have been accustomed in hot weather to wear a net next the skin and a thin silken garment over the net. The net, without increasing the heat, prevents the sweat soaking into the upper garment, and the latter from adhering to the skin, and nothing can be conceived more suitable for tropical heat than such an arrangement.

For preventing the effects of solar rays upon the body the colour of the fabric worn is all-important. White garments absorb least heat, and are the best for the tropics. Next to white for resisting the effects of sun-heat

are the light shades of colour. Blue and black are the worst, and absorb heat very readily.

We are now in a position to discuss the articles of clothing employed for different regions of the body.

The head first demands our attention. Being provided with a natural covering in the shape of hair, it really requires no additional clothing, as the state of well-being enjoyed by the London Blue Coat boys sufficiently shows; but the usages of society render it inadmissible to go without a head-covering of some kind—at least out of doors—and a man who is accustomed to wear a hat is tolerably certain to catch cold if he goes without one.

The hair of a man should be worn short, and the shorter it is the more readily it is kept clean and tidy. When the hair is short it can be washed almost as easily as any other part of the body, and in a town such as London, where the atmosphere is laden with soot and dirt, the frequent washing of the head is an absolute necessity. The custom of applying some pomade to the hair is very general, and it is probably a good custom; when the hair is slightly oiled it can be the more readily combed, and the combing, brushing, and oiling serve very materially, not only to keep the hair clean, but to free it from vermin as well. A little oil or similar material having a basis of glycerine or vaseline also prevents the drying of the skin of the scalp and checks the tendency which the surface epithelium has to come off in the form of scurf or dandriff. A very greasy head not only looks disagreeable, but from its stickiness it enables dirt easily to lodge upon and adhere to the hair. The abuse of pomades is to be decried from every point of view; but the 'pennyworth of hair oil,' which forms so important an adjunct of the Sunday toilet of the working classes, is not to be discouraged.

It is quite possible to go without a hat in any climate, and natives of the tropics who wear the hair short and have no artificial covering for the head do not seem to be liable to sunstroke, nor are their eyes dazzled by the glare of the sun.

In very cold regions also the hair if tolerably thick is sufficient protection for the head, and might also be made to cover the ears; but if the hair be not thick, then a head-covering becomes a necessity, and, as a matter of fact, most of the inhabitants of northern climates find it convenient to cut the hair and cover the head with a fur cap having lappets for the ears.

For ordinary use in a climate like England the selection of a hat is not a very important matter, the main consideration being the comfort of the wearer. It is important to have a layer of air between the top of the head and the crown of the hat, for in this way the effects of cold and heat are alike avoided. It is also advisable to have a certain amount of rigidity in the hat as a protection for the head from the effects of falls or accidental blows. The low-crowned hemispherical hat of felt with a brim sufficient to protect the eyes from glare and to keep rain from running down the neck meets most of the indications above mentioned, and its popularity is quite justifiable. The tall cylindrical 'chimney pot' hat made of silk is by no means a bad headdress, notwithstanding the abuse which is levelled at it. It is not very heavy (at least it need not be), it has sufficient stiffness to protect the head, and the large stratum of air between the head and the crown of the hat is excellent. The comparative narrowness of the brim, the cylindrical shape, and the smooth surface make it difficult to be blown off, a point of no small importance. Its great drawback is its cost and the ease with which it is damaged by rain. A shabby hat of this description gives an air of shabby gentility, and there is nothing which more degrades the appearance of a man than a mangy hat which has seen better days.

Some of these hats are made to 'ventilate,' with the idea of keeping the head cool. A drawback to the two varieties of hat mentioned is the difficulty of keeping them clean, but in this respect the cylindrical hat is usually better than the hemispherical 'deer-stalkers.' These catch the dust very badly, and the combination of dust and rain spoils them very rapidly. Dust lodges especially round the brim, and the brim is of such a shape that only brushes of a very special make will clean it. Every traveller must have experienced the shortcomings of these hats, and it is much to be desired that the curl to the brim and the conventional bow of ribbon at the side may some day be dispensed with. For comfort there is probably nothing better than a soft felt 'wideawake,' but their crumpled appearance and the ease with which the wind 'takes' them are to be reckoned among their disadvantages.

In very hot weather a white and very light 'chimney-pot' is really a first-rate headdress. A straw hat of a light colour is also a comfortable thing in hot weather, but the generality of straw hats are too low in the crown, which is often absolutely in contact with the top of the head. A straw hat of the 'chimney-pot' shape is comfortable, but not in favour among æsthetic people.

A very important point in the choice of a hat is its weight, which should be as small as is consistent with the other purposes for which the hat is needed. A conventional black silk cylinder weighs about 6 oz., and the common round felt hat about as much. A white flannel cricketing cap weighs between two and three ounces, and the Grenadier's 'bearskin' about 35 oz.

There are a variety of hats for special purposes. For protection against the direct rays of the sun there is probably nothing better than the turban, its chief drawback being the trouble of adjustment. To avoid this the white pith or cork helmet, with ventilating holes at the top and round the rim, has been devised, and is said to be a most efficient protection. A further protection to the head is afforded by a gauze 'veil' twisted round the hat and with the ends falling over the nape of the neck in order to protect the medulla oblongata from the direct action of the sun's rays. The Boers of tropical Africa wear felt wideawakes with broad brims, and the planters in tropical America wear straw hats with wide brims. If the brim be not wide, then a veil or 'puggeree' becomes necessary.

The principles to be followed in providing a headdress for women are different because the true headdress of women is the hair, and any additional headdress is only for the purpose of keeping the hair clean and for adornment. When women take up masculine pursuits they usually adopt headdresses similar to those worn by men. Ladies' hats and bonnets are made solely in compliance with the dictates of fashion, and there is no possibility of discussing them with any advantage.

With regard to the clothing of the body the main objects are—

1. To maintain the temperature and by preventing the loss of animal heat to diminish to some extent the demands for food. Warm clothing is economical, but it unfortunately generally happens that those who are unable to be warmly clad are also insufficiently provided with food, and these two evils intensify each other. 'Starved with the cold' is a very old expression, and one which has a basis of physiological truth, for if the body were warm, the want of food would be less keenly felt, and *vice versâ*.

2. To allow the chief heat-regulating mechanism (i.e. the evaporation from the skin) to proceed with as little hindrance as possible.

3. To allow all muscular acts the greatest possible freedom, and to avoid the compression of the body in so far as may be possible.

4. To protect the body from heat, cold, wind, and rain.

5. To disguise as little as may be the natural beauties of the human figure.

The most important part of our clothing from the hygienic point of view is that which we wear next the skin, the underclothing. The thickness of this must vary with the season, from the stoutest flannel to the thinnest gauze. Wool is probably the best material for all seasons, and if cotton or linen be employed it should be loosely woven, so that it may entangle a maximum quantity of air in its meshes. In very hot weather or in the tropics a net is an excellent form of under-garment. The 'cut' of underclothing is most important, and the fashion which has lately come in of making the under-vest to fasten on one shoulder is excellent, so that any accidental exposure of the front of the chest to the wind is thereby avoided.

Underclothing should fit so as to follow tolerably closely the outline of the figure without impeding the movement of the arm. In winter it should come well above the sternal notch and the sleeves should extend to the wrists. It must not compress the thorax, abdomen, or arms. A recent improvement in underclothing is the 'Combination' garment, i.e. vest and drawers in one. In this way the band for the drawers is avoided and the necessity of compressing the abdomen by a band is done away with, as is also the annoyance of a double or even a treble layer of material round the loins. The perspiration at this spot when vigorous exercise is taken is often excessive: the band of the drawers gets wet through and the risk of chill when exercise is ended is considerable. Another advantage of this garment is the lessening of the number of chinks through which the wind may gain access to the body. A most important matter from a practical point of view is the ease with which garments may be unbuttoned and adjusted so as to obey the calls of nature with the greatest readiness, and in purchasing 'Combination' garments this point must receive attention.

The drawbacks of flannel underclothing are mainly two—viz. the irritation which they often cause on the skin, and their liability to shrink when washed. Some persons are unable to tolerate flannel next the skin because of the irritation which it causes. Such persons have usually a quick circulation, and are not liable to chilliness; but if great protection is necessary wash-leather over silk is probably the warmest combination obtainable.

The liability of flannels to shrink in washing is more serious; but this drawback may be greatly reduced (*a*) by 'shrinking' the flannel thoroughly before it is made up and (*b*) by washing in cold or tepid rain water and avoiding too much friction with the hand. Flannel garments should be soaped on both sides and then rinsed by waving them to and fro in a large quantity of cold soft water. It is asserted that in the tropics there is no need to wash flannel. If a shirt be hung up to dry in the sun and thoroughly beaten when dry it is said that its cleansing is thoroughly effected and that no foul odour clings to the material.

Underclothing should be frequently changed, but the necessary frequency must depend upon the amount of sweating and the state of the skin, which differs greatly in different individuals. If the skin be thoroughly cleansed and rubbed every day a suit of underclothing may be worn for the conventional week without contracting any animal odour, but this is only possible when the weather is cold and the individual has taken no very vigorous exercise to produce sweating.

In providing the outer and visible clothing of the body regard must be

had to the same principles which guide us in the provision of the underclothing. The principle of the survival of the fittest would lead one to suppose that there is not much amiss with male clothing, for it has remained substantially the same for the last sixty years.

The *shirt* is most comfortable when made of flannel or some soft mixture of wool with other fibres. A flannel shirt over woollen underclothing is very warm in winter, and worn alone without underclothing is the perfection of a dress for the summer.

In the dirty atmosphere of London a flannel shirt soon gets grimy and looks slovenly and dirty. If, therefore, it be worn in town, mild deceptions are practised in the matter of collar and wristband, and the front is concealed with a scarf. The highly starched linen shirt, with its polished front, collar, and wristbands, has no hygienic merit except its cleanly appearance, in which it is unsurpassed. There probably never has been a garment so capable of making a man look clean and smart at a comparatively small cost as the modern shirt. The appearance of cleanliness holds the first place from an æsthetic point of view, and that which looks clean and fresh is sure to be popular. A Londoner without being thought excessively dandified or extravagant may have his two clean shirts per diem, and with them he probably looks cleaner and fresher than he would in the costly lace ruffles which were in vogue in the eighteenth century.

The *waistcoat* is a most useful and valuable article of clothing. Originating as a very voluminous garment—apparently in the time of Hogarth (about 1738)—it got smaller by degrees until it reached its present very modest proportions. The waistcoat does not (or rather should not) impede the movement of the body in the smallest degree, and it can be regulated to suit the season and the occupation with great readiness. Between the low-cut white waistcoat which is worn indoors and the high sealskin waistcoat lined with flannel we have all gradations of warmth, and there is no doubt that this garment is of the greatest practical utility. In the present day coats vary immensely in 'cut;' but the 'cut' of the waistcoat scarcely varies at all. It is difficult to imagine what we should do without the waistcoat pockets, which are at once safe and convenient.

A 'sleeved' waistcoat is a very warm garment, and a very useful one for those who have to encounter a mixture of active work and inactivity, such as railway porters, who would be much inconvenienced by a coat, and who are too much exposed to weather to work 'in their shirt-sleeves.'

What can be said of *coats*, except that they should fit and allow absolute freedom of movement to the arms, diaphragm, and abdominal muscles without forming creases?

The writer is not one of those who is disposed to cavil at modern male attire. In the main it is comfortable and sensible, and it is very hard to believe that the Cavalier of the seventeenth century, in all the glory of gold, velvet, feathers, and curled hair, had any advantage in the matter of appearance when compared with the spotlessly clean and exquisitely neat gentleman of the nineteenth century. Ostentation in the matter of dress on the part of a man would at the present day merely raise a laugh. The duke and his butler are both contented with a white shirt and a black suit of clothes, and the fact that the wealthy are content with the same simple clothing as the comparatively poor may, we think, be taken as evidence that our universally adopted garments have reached a high degree of perfection, from the point of view of comfort and suitability.

It is needless to say that coats vary in accordance with the work to be done. Tails and skirts are necessary from an æsthetic point of view, when

with advancing years the figure becomes protuberant. They are also very useful as furnishing space for pockets. Tails and skirts hamper movement, and do not materially increase the warmth of the garment. One of the warmest and best garments for winter wear is the 'pilot' jacket, which buttons up and affords first-rate protection to the chest and abdomen, while it does not in any degree impede the movement of the legs.

When a garment is worn for warmth it is all-important to protect the abdomen and chest. If this be efficiently done it is not so necessary to protect the limbs. The Highland kilt is said to be a very warm garment, because it extends nearly up to the level of the armpits, and being thickly pleated it affords a very great deal of protection to the trunk.

From a purely hygienic point of view, however, the bare knees of the Highlander are as indefensible as the 'bearskin' of the Grenadier.

For very cold weather and for travelling, fur-lined coats are much used. The protection they afford is enormous, but they are too heavy for walking in. The same may be said of the modern 'ulster,' which is a warm but very cumbersome garment.

In very variable climates, such as the south of Europe, where the extremes of temperature are very wide apart and the fluctuations sudden, it is usual to wear a cloak loosely hung upon the shoulders, in order that the body may be enveloped by it at a moment's notice should the occasion arise, as it frequently does, especially at sunset.

The clothing of the legs, as far as man is concerned, resolves itself into a question of *trousers* or *knee-breeches*.

Trousers have the great advantage of compressing the body at no point, and of allowing the greatest freedom of movement to the leg. The great freedom of movement in trousers is shown by the fact that they are universally worn in the cricket field, where the body is called upon to undergo very sudden changes of position. Cricket is a game which involves the keenest competition, and concerning the dress to be worn while playing cricket there are no laws or regulations. It is tolerably certain that no point, however small, which could give one side an advantage over the other would be neglected. The fact, therefore, that the dress of cricketers is practically the same the whole world over is very important, and constitutes the strongest testimony that the trouser places no appreciable check upon the movements of the body. In the cricket field, where the trousers worn are of very light weight and there is nothing worn beneath them, a buckle to draw them in over the hips is sufficient to keep them from falling. At other times it is necessary to support the trousers with something more secure, and to this end 'braces,' which pass over the shoulder, are now universally adopted. There is no doubt that braces are preferable to a belt, inasmuch as they do not compress the abdomen, and scarcely interfere at all with the movements of the limbs.

The drawback to trousers consists in their liability to get dirty and wet round the bottom, and the tendency of fashionable tailors is to make them decidedly too long. This fault in trousers is so easily met by turning up the ends that it scarcely deserves mention. Nevertheless, trousers might be worn shorter than at present with obvious advantage.

The old-fashioned pantaloon, or trouser which buttoned round the lower part of the leg, had some advantages, and when worn with the high 'Hessian' boot was an excellent arrangement for sloppy, dirty weather. The boots could be easily removed and replaced by clean shoes; but in spite of these advantages the pantaloon had a short reign, and it is certain that it hampered the movement of the leg more than the trouser.

Knee-breeches, or knickerbockers, constitute an excellent garment for walking, from the point of view of cleanliness and comfort. They involve compression of the leg below the knee in order to support the stocking, and the compression is seriously felt if the knee be bent beyond a right angle and the wearer suddenly assume a squatting position.

The knickerbocker and the pantaloon as compared with the trouser have the obvious disadvantage of possessing more buttons and fastenings, and the fact that the legs can be clothed quicker in socks and trousers than in any other garment, and the additional fact that the trousers have fewer buttons to *come off* than any other garment, are practical points which do much to maintain the popularity of the trouser. The great popularity of the knickerbocker among touring pedestrians is to be attributed to the small space occupied by a pair of stockings in a knapsack and the ease with which stockings can be changed when the journey is over.

For cycling, knee-breeches and stockings are almost universal. In this mode of progression the flexion of the knee is seldom excessive, and the loose end of the trouser is liable to hitch in the mechanism of the cycle. These facts, as well as others, make them popular for cycling.

For rowing, which necessitates an attitude suggestive of the letter N, any compression round the knee is not to be thought of. The Highland kilt undoubtedly allows great freedom to the legs, especially the knee-joints, and those who wear it habitually protest that it is not cold. For walking through brushwood or covert of any kind, both the skirt of the kilt and the naked knee are alike objectionable.

The principles which hold good with regard to women's clothing do not differ essentially from those which should regulate men's attire. Volumes have been written on this subject, but, except in the top garment, the 'dress,' it does not appear that women's attire has altered more than that of men. It is an essential part of all costume for either sex that it should readily admit of an immediate obedience to the calls of nature, and the main cause of the difference of costume in the two sexes is the difference in the anatomy of the urethra. This is a point which is, of course, kept in the background in all popular treatises. We do not intend to discuss the relative advantage of the single and the divided skirt, which is a matter which women must regulate for themselves. Again, on the question of 'stays' or corsets, there would appear to be room for two opinions.

There can be no doubt that any undue compression of the waist is thoroughly bad and most mischievous. If the respiratory and abdominal muscles be not free to act, they will not develop properly, and if the waist be 'laced in,' the heart, lungs, liver, and stomach are thrust upwards and the intestines forced downwards. Discomfort after meals and serious dyspeptic troubles must and do result, and these are followed by anæmia. The commonest symptom of dyspepsia in a woman is pain under the left breast; a symptom of which men rarely complain; and the reason for this difference of symptom of the same disease in the two sexes is due probably to the displacement of the stomach by the stays. The chief defence of the stays is found in the statement that they are necessary for the support of the petticoats and skirts. There can be no difficulty in supporting the skirts from the shoulders, but fashion steps in to prevent this; and there can be no doubt that the fashion of appearing with naked shoulders on state occasions prevents the general adoption of what seems to be a sensible reform. For one who was accustomed to wear braces, or some substitute for them, the ordeal of going to a high ceremony without them would be most trying. A lady's full dress,

which involves a bodice having practically nothing over the shoulders, must take its bearings from the waist.

The weight of winter skirts and petticoats, especially with a brocaded 'train' yards long, must be prodigious, and were it not for a stiff corset firmly poised upon the hips, the carriage of such gear without shoulder-straps would be impossible.

The articles of clothing for the feet—socks and stockings, boots and shoes —probably influence our comfort more than any other portion of our attire.

Like many other articles of clothing, they are said to be unnecessary, and we are told that the naked human foot soon gets accustomed to variations of temperature, and 'the thousand natural shocks' which are inseparable from labour and locomotion.

Be this as it may, it has been the custom of all civilised races from remotest periods to clothe the foot, and there is no probability that this custom will be departed from.

In considering this subject we must deal with it in the first instance in relation to utility, i.e. to foot-coverings, in which a man can work or take vigorous and active exercise. As to 'dress' boots and shoes, articles which are worn mainly for decency or adornment, and in compliance with the dictates of custom, that is another matter upon which one may treat lightly.

In considering 'foot-coverings' we must remember that the boot is only the outer covering of the foot, and that within it is the stocking or sock. With regard to the stocking or sock, this should always be of a woollen material, or of a mixed material in which wool predominates. The hygroscopic qualities of wool cause it to absorb the perspiration of the foot, and its elasticity as a woven fabric and its power of stretching make it less liable to form creases and to give rise to the consequence of creases, i.e. blisters and corns. A sock should 'fit,' i.e. it should have in its material neither poverty nor riches; it should not cramp the foot, and should form neither folds nor creases. Its substance must vary with the time of year, the work to be done with the foot, the kind of boot to be worn, and the fancy of the owner. A sock should be without any projecting seams. Ribbed stockings or socks are comfortable, and allow some slight circulation of air between the sock and the boot. Socks may be made 'right' and 'left,' and when thus made they undoubtedly fit more accurately; but this is perhaps an unnecessary refinement, as there is always room to spare in the toe of a sensibly made boot above the fourth and fifth toes, and if there be a little redundancy of fabric at this point it causes no inconvenience. When very thick winter socks are worn it may be an advantage to have them 'right' and 'left.'

A greater refinement than having the socks right and left is to have them digitated, with compartments for each toe. This may be necessary for those who have pathological conditions of the feet, such as soft corns between the toes, or an inordinate tendency to perspiration between the toes. If socks be digitated, then accuracy of fit becomes doubly necessary. Again, a woollen digitated sock would probably not be very comfortable after a few washings and darnings.

There are those who maintain that even if boots be worn socks and stockings are unnecessary. If socks be not worn the boots must be very well made and perfectly free from projecting internal seams or anything else likely to rub against the foot. If the boot be suitably made of supple leather, and if the foot and boot be greased internally, it is probable that walking may be accomplished with great comfort, and if the boot be kept clean inside as well as out (i.e. if a filthy, blacking-bedaubed hand be not inserted into it for

cleaning, as too often is the case), the foot will wash perfectly clean, and no staining or galling will result. If no socks be worn, it follows that the boot may be slightly smaller and lighter, which is an advantage during a long walk; but when the pedestrian halts, especially if he halts in a cold place, such as a mountain top, the feet are apt to chill, because leather is a good conductor of heat. If, however, the pedestrian is not going to incur any such risks, and can change to a pair of socks and shoes when the walk is over, it is probable that there are many advantages in having no socks or stockings. For this practice to be successful, the boots must be first-rate and must fit accurately. When pedestrians wear roughly- and ready-made boots, as is the case with soldiers, a sock is absolutely necessary, and it is said that those who wear no socks are in the habit of wrapping a piece of linen round the toes to preserve them from bruising.

If no socks be worn the boot must be rather high in the upper, and must fit well round the ankle, so as to prevent dust or small stones finding an entrance to the boot.

For indoor wear upon carpets there is no objection to socks of linen, cotton, silk, or any material which the wearer fancies, provided he be not liable to cold feet, in which case 'merino' is probably the best material. Cold feet are to be avoided, especially at night, as if the feet get chilled there is apt to be an undue supply of blood to the head, and sleeplessness very commonly results. As to the colour of socks, the wearer may follow his fancy provided they be properly dyed. Some years ago there were reported cases of eczema of the legs which resulted from wearing 'magenta' socks dyed with an aniline product. In this instance the real cause of the eczema was the employment of an arsenical compound as well as the aniline compound in the process of dyeing.

When stockings are worn the question of 'garters' or some substitute has to be considered. Any compressing band round the leg is very undesirable, and it is advisable, especially for children and growing persons, to use 'suspenders' for the stockings rather than garters. If garters be worn, there is nothing better than the old-fashioned knitted garter, which is a very good compromise between the requisite elasticity and firmness. Garters must be worn below the knee, as, if they be placed above the knee, any strong contractions of that joint must work the stocking from beneath the garter, and the garter, when worn above the knee, must be drawn inordinately tight in order to prevent such a mishap.

Next as to *boots*, the best material is probably that which has been mainly used for centuries, viz. leather. Good leather is very pliable, and is hygroscopic and absorbent, so that perspiration is absorbed and slowly given off again. Leather, too, is very durable, and nothing wears better for the sole of a boot than old-fashioned English oak-tanned leather, although it is doubtful if the same thing can be said for some of the chemically prepared substitutes for that article. Leather is sufficiently waterproof for most purposes, and a stout, well-made boot, especially if it be greased, will keep out anything but very excessive amounts of moisture.

Impermeable materials are very undesirable for boots, and no one who has tried to walk long distances in 'patent leather' boots would wish to repeat the experiment. In all cases the perspiration absorbed by the inside of the boot must be able to be given off again from the outside.

India-rubber is a very undesirable material, especially for the uppers, although there is no objection to it for purposes other than walking, such as standing in water for fishing, &c., and for wearing on board ship when the decks are wet.

The writer was lately consulted by a gentleman who was troubled by swelling of the feet, and as there was no kidney disease, or heart disease, or any detectable cause for local obstruction to the circulation, the cause of the swelling was for a time a mystery. On questioning him it turned out that he had been for some time in the habit of walking about his farm in 'deck boots,' that is, boots made of india-rubber lined with green baize, and this was the probable cause of his trouble, the feet and legs having been practically poulticed by his hot, impermeable boots for many hours daily. These boots were discarded and the swelling disappeared.

Coarse canvas is now very often used for the uppers of lawn tennis shoes, and there is no objection to this, but canvas is unsuitable for boots meant for hard wear, as it does not resist moisture sufficiently.

The soles of boots are not unfrequently made of india-rubber or gutta-percha, and although the objections to the use of the material are not so great as when the uppers also are made of it, it is probably inferior for soles to the time-honoured leather.

Volumes have probably been written on the proper shape for boots, but when it is said that a boot should fit the foot accurately what more can be said? The shape of the sole of a boot should be taken by drawing a pencil round the outline of the foot, when the bootmaker's 'patient' is standing up, so that the sole may be big enough to support the fully expanded foot. That the line of the first metatarsal bone and the phalanges of the big toe should be straight goes without saying. When we say that a boot should fit, we mean that, without being loose, the foot should have room to move in it, and on putting on a new pair of boots the wearer ought to be able to move all his toes with freedom. Not only should the lower part of the boot fit, but the upper part also. This often is not the case, for even in what are called 'bespoke' articles the upper is not unfrequently 'ready-made,' and is merely the nearest approach to a fit which the bootmaker could procure. It is undoubtedly true that 'ready-made' boots may fit accurately, but it is only a happy chance if they do so, and seeing that the contour of the foot is not precisely the same in any two individuals, it follows that if a man have tender feet his best course is to go to a first-rate bootmaker and have the boot made for him *throughout*. Ready-made boots have this fault, that the unintelligent steam machinery which turns them out does not consider the endless varieties in shape which the human foot presents.

Boots which do not fit cause deformities of the feet, and especially in early life. Among the Scotch and Irish peasantry the children of quite respectable parents wear no boots, and this causes a proper development of the foot during the periods of active growth, and the feet are free from corns or bunions, and the liability to chilblains is probably less if the children be well nourished. Undoubtedly when such children have to adopt boots they pass through some discomfort, but their chance of being properly fitted and not pinched is probably greater than among those children whose feet have become deformed by improper boots.

Boots are a great expense to the poor, for it is doubtful whether children grow out of their boots or wear them out the more quickly. This often results in their being provided from economical reasons with boots which are too heavy and too big, and thus their exercise is often hampered and their feet often bruised.

Children should, if they wear boots, have them renewed, not only in accordance with the wear of the boot, but also with the growth of the child. If this be not done the foot gets compressed and distorted, and the toes have a tendency to overlap, and chilblains are common. Growth does not stop

much, if at all, before twenty years of age, and sometimes continues after that period, so that young ladies and youths should have great attention paid to their boots in order to prevent troubles which may last them through life.

From some points of view shoes are better than boots, as the latter are liable to compress the muscles and tendons in the neighbourhood of the ankle, and so weaken them and prevent their proper development. The cause of 'weak ankles' is to be found as often as not in an unwise compression of that region, and although a firmly laced, well-fitting ankle boot undoubtedly supports the ankle, it also prevents the ankle from learning, so to say, to support itself. Shoes have the disadvantage of allowing sand and dirt to get in over the upper edge, and there is no doubt that when shoes are worn the socks are dirtier after a long walk than when ankle boots are worn. When shoes are worn for heavy work some sort of gaiter is necessary, but this introduces a complication into dress which occupies time in cleaning and putting on and off, so that, all things considered, it is probable that ankle boots, which are now so generally worn, are for ordinary purposes the best. We are seldom wrong in concluding that that which is generally worn, and is not worn merely in obedience to a caprice of fashion, has some very solid and practical merits.

For hard walking, high boots such as come up to or approach the knee are too hot, but for slow walking, such as partridge shooting in wet turnips, the high boot which laces up the middle, and which is really a boot and gaiter in one, has undoubted merits.

The so-called 'Wellington' boot or 'half Wellington' with a high upper, and which has no fastenings, but merely slips on and off, has great advantages in the fact that the wearer is never the victim of broken laces or absent buttons. Their drawback is the heat of them and the fact that unless they be unduly loose they are apt to be very difficult to get on and off after a prolonged soaking in wet ground. The German Army boot is, it is right to say, of this pattern.

The sole of a boot should be wider than the foot, and if the boot is to be used for heavy walking this excess of breadth in the sole should be considerable, so as to serve as a protection from rocks and loose stones. The thickness of the sole must vary according to the work to be done. In a variable climate like ours it is always advisable to wear soles of some substance, just on the same principle that it is wise to be provided with an umbrella even if the sun be shining. The thicker the sole, the less pliant it is, and a rigid sole is bound to wear out, at the toe especially, for in walking the heel is first placed on the ground and the last act is the final push against the ground with the point of the big toe, and if the sole be too thick to bend the toe must get worn out long before the sole at large. The outside of the heel and the inside of the toe are the two normal points of main wear in a boot, the centre of the sole (slightly on the outside) being the third point. Man shows his descent from the ape by walking slightly on the outer side of his feet. Thick or 'clump-soled' boots are generally made thin in the waist from the mistaken notion that this gives pliancy to the sole. As a matter of fact, the waist of a boot has no tendency to bend at all, the line of bending being further forward exactly beneath the crease which forms on the top of a boot which has been worn, that is, a line extending obliquely from the metatarso-phalangeal joint of the big toe to the corresponding point of the little toe. Boots have been made with a sort of hinge in the sole taking the course of this line, but as the strength of a sole is to be measured by the strength of its weakest point, and as the 'hinge' is necessarily a weak point into which moisture and grit are liable to find their way, it is doubtful if this plan is

practically of much use. The wear and resisting power of a sole is to be measured more by the thickness of the individual layers of leather than the thickness of the sole as a whole. For a sole may be very thick and yet be made mainly of rubbish. The middle layer of the three which form the sole of an ordinary 'double' (i.e. really treble) soled boot is often of inferior quality, and directly the outer layer gets worn the middle layer readily absorbs moisture. A stout single sole (i.e. a sole of two layers) is a better protection than one of three thinner layers, and has the advantage of being lighter. It is doubtful if for heavy work a moderately heavy boot is any disadvantage. An ordinary pair of walking boots weigh about two pounds, a thick pair nearly three, and a pair of very heavy shooting-boots with nails weigh about three and a half pounds. This weight is nothing for the legs of a moderately active man, and if the ground to be traversed is rough a pair of big boots is a great advantage, especially in coming downhill. Professional walkers and professional mountaineers all adopt heavy boots. It may be well to remark that big hob-nails have certain advantages, of which the increased 'wearing' power is only one. They give a very firm hold of the ground and are very necessary for mountaineering, and especially on slippery grass slopes. They are the only things which hold satisfactorily to a 'greasy' pavement. They raise the sole of the boot off the ground and help very materially to keep the foot warm and dry, and further they are very clean; and in walking on sloppy ground (such as a pavement during a thaw), they splash very little. They should always be worn by those who are obliged to be out in all weathers, such as soldiers, policemen, postmen, &c. To obtain these results only a very few nails are necessary, but they must not be too few, because if the points of pressure of the nails are not sufficiently close they are apt to make their pressure felt upon the foot itself and cause sores or corns. Again, if the nails be too far apart to give each other some mutual support they are sure to kick out. Nails are now made with projections in the head which stick into the sole, and such nails are very firm. The plan of inserting nails in groups of three, so that each nail is supported by the other two, is also a very good one. Screw nails, again, are absolutely firm, but necessitate a great thickness of leather to hold the screw.

The heels of boots have been much written about, and it is tolerably certain that they are no help to progression, and from the purely physiological point of view are useless. The heel of a boot is the first point to wear out whether the heel be raised or not, and as the ordinary raised heels are very easily repaired they are economical, and it is probably due to this fact that the fashion of 'heels' has lasted for centuries. They serve also to keep the foot off the ground and help to keep it dry, and they also probably serve to prevent splashing, which is a very legitimate æsthetic and practical consideration. The heels of boots should most certainly be low and broad, and a high tapering heel which lessens the basis of support for the body is absolutely indefensible. The inordinately high heels which are worn by some ladies, by raising the hind part of the foot, diminish its apparent length, and this undoubtedly is the cause of the persistence of this fashion. It is needless to say that they cause the foot to look deformed and make active locomotion impossible by effectually taking away the power of 'spring' from the foot, and by throwing undue pressure on to the unfortunate toes which are crowded together in this irrational foot-gear. High heels increase the apparent height of the individual and they apparently are much admired by men, which probably accounts for their almost universal use upon the stage and in other public places.

It needs hardly to be said that dancing in any true sense is impossible

in high-heeled shoes. The last of the famous dancers who really displayed the true poetry of motion was probably Madame Taglioni, and it is perhaps worth recording that this lady always wore a pair of simple absolutely pliant satin slippers without heels of any kind, and fastened by slender elastic bands. The modern ballet shoe has an absolutely rigid toe, so as to enable the *danseuse* to perform the *pas des pointes*, which seems to be the *sine quâ non* of modern stage dancing, which, whatever may be its merits, most certainly is not dancing.

If the object of foot-gear be mainly to keep the foot warm, then undoubtedly woollen materials or fur linings are advisable.

The Chinese shoe, which is admirable in this respect, has a sole about an inch thick, made of layers of thick paper or felt, and by this means the Chinaman, who seldom indulges in very active exercise, and who never employs carpets in his house, is enabled to keep the foot comfortably warm, even in the depth of winter. Slippers made of felt are admirable for keeping the feet warm indoors, as is also the slipper with a hempen sole, which is so largely worn in the Basque Provinces and elsewhere in the south of Europe. A cloth or woollen top to the boot is a most comfortable arrangement for winter.

The wooden shoe, or sabot, and the Lancashire clog, which is a sabot shod with iron, is a very cheap and serviceable foot-gear for working in sloppy places, and it has the advantage of being put on and off in a moment. The old-fashioned patten, which used to be so much worn by women engaged in sloppy work, is also a very admirable and simple contrivance for keeping the feet dry under certain conditions.

The American overshoe and the 'golosh' need only to be mentioned as very useful things for temporary purposes, but quite useless when rapid or prolonged locomotion is required.

Before leaving the subject of foot-gear, it may be mentioned that it is very advisable, and especially for delicate persons, to be careful to change the shoes and stockings after active exercise, as the cold produced by the evaporation of the perspiration is very liable to chill the feet. If the feet get wet in the course of exercise it need hardly be said that this precaution is doubly necessary. There is little danger in getting wet feet or in being wet through provided the pedestrian keeps moving, but if he neglect to change his clothing immediately his exercise ceases he is sure to get 'a chill.'

Our remarks hitherto have been solely directed to working boots, but perhaps in a subject of so much importance it may be permitted to say a few words on the æsthetic side of the subject, and be it remembered that trained æsthetic faculties are the true aids of the hygienist, because the first canon of æsthetic law with regard to clothing must be cleanliness. No article of clothing which is not clean can possibly please the eye, and therefore the first consideration with regard to boots is facility for cleaning. As the English stand almost alone among European nations in the art of boot cleaning, it is to be presumed that our common methods in that respect are sound; and indeed it is hard to imagine anything more satisfactory to the eye than a black leather boot thoroughly polished with 'blacking,' which is a carbonaceous mixture, the fine particles of which can be made to shine by brushing.

A material which makes a boot appear clean and brilliant without interfering with its porosity or pliancy has qualities which are of great value, and if it had not the disagreeable property of soiling the hands and clothing which come in contact with the boot, its popularity would be assuredly

permanent. No varnishes can be regarded as in any sense a substitute for blacking, for in the first place they destroy the porosity of the leather, and in the second place the application of layer upon layer makes the surface of the leather uneven, and suggests filthiness rather than cleanliness. Varnishes do not soil the hands, which is some advantage.

Bootmakers do not sufficiently consider the comfort of the wearer in small matters. Why should new boot-laces be soaked in carbon and grease up to their very ends? Why should not that part of a lace which is touched by the hand be left free from soiling impurities?

There is, just now, a fashion for boots made of brown and 'tan' leathers, a fashion which had its origin among military men engaged in tropical campaigns. The light tint of these leathers make them cool for the feet, and this fact, combined with cleanliness, has done much to make them popular. From an æsthetic point of view they appear to be surpassed by polished black, which gives to even an old boot an appearance of absolute cleanliness, which the tan leather never has, and least of all when old and stained. Nothing makes the outline of a foot appear so small to the eye as when it is clothed in black, with a polished surface which reflects the light.

A boot to look well should show the outline, and should not conceal the movement of the foot, which is one of its chief beauties. The beauty of a foot consists, not only in its outline, but in its elastic pliancy and its proper proportion to the rest of the body. 'Small feet' are considered a beauty, but there can be no doubt that a foot should bear a due proportion to the body. A man with inordinately small feet is apt to have an appearance of effeminacy and feebleness, which is not pleasing to any healthy æsthetic sense; and when we see a man with his feet crammed into tight high-heeled boots, so that he is compelled to 'strut,' instead of walk, it is hardly possible for our 'first impression' not to be one of slight contempt.

As boots and shoes necessarily add to the apparent size of the foot, it is very important that nothing in their design should unduly add to this æsthetic drawback. To this end foot-gear should be uniform in colour. A mixture of tints and elaborate patterns (checks, &c.) undoubtedly make the foot look large, as do also big bows and rosettes.

The weight of clothing is considerable, but necessarily varies with the season of the year. The following are the weights of the ordinary civil attire of a man weighing 133 lb., and 5 feet $6\frac{1}{2}$ inches in height:—

		Lb.	oz.		Lb.	oz.
Socks	from	0	$1\frac{1}{4}$	to	0	4
Under-vests	,,	0	$3\frac{1}{2}$	,,	0	$13\frac{1}{2}$
Under-drawers	,,	0	$4\frac{3}{4}$	,,	0	$12\frac{1}{2}$
Shirts	,,	0	$9\frac{3}{4}$	,,	0	13
Trousers	,,	0	15	,,	2	2
Waistcoat	,,	0	7	,,	0	$12\frac{1}{2}$
Coat	,,	2	$5\frac{1}{2}$	,,	3	1
Boots	,,	1	7	,,	3	0
Collar	,,	0	$0\frac{3}{4}$	,,	0	$0\frac{3}{4}$
Handkerchief	,,	0	$1\frac{1}{2}$	,,	0	$1\frac{1}{2}$
Cravat	,,	0	1	,,	0	2
Total weight of clothes		6	9		11	$14\frac{3}{4}$

Thus it is seen that the weight of clothes which may be worn in summer and winter varies considerably.

When out of doors there are considerable additions to be made, thus:—

		Lb.	oz.		Lb.	oz.
Hat	from	0	2	to	0	7
Scarf	,,	0	0	,,	0	3
Gloves	,,	0	$0\frac{3}{4}$	,,	0	4
Overcoat	,,	2	$12\frac{1}{2}$	,,	8	0
Umbrella	,,	1	$1\frac{3}{4}$	,,	1	$1\frac{3}{4}$
Keys, money, watch, &c.	,,	2	10	,,	2	10
Total extras		6	11		12	$9\frac{3}{4}$

Thus it appears that a man in walking attire in the winter may have to carry as much as 24 lb. $8\frac{1}{2}$ oz., or rather more than 18 per cent. of the weight of his body. Of this weight only 7 oz. is carried on the head, and 3 lb. 4 oz. on the feet, while 2 lb. $14\frac{1}{2}$ oz. are suspended from the shoulders and partly supported by the hips; while of the remainder 16 lb. $9\frac{1}{4}$ oz. are carried entirely on the shoulders and 1 lb. $5\frac{3}{4}$ oz. are carried by the hands.

There can be little doubt that the shoulders are best able to carry the maximum weight, and the writer is not prepared to offer any adverse criticism to the distribution of the weight of the clothing given above. The pedestrian often has to carry a knapsack, and the problem of how best to distribute the weight arises. Heavy weights are carried after a little practice on the head with great ease, and it is probable that the carrying of weights upon the head is a sure way of producing an upright carriage and graceful figure. If the weight be divided between the head and shoulders by means of an apparatus which may be seen any day in Covent Garden Market, very heavy burdens may be carried with comparative ease. Such methods are, however, impracticable for the traveller, and the shoulders and hips are the points upon which a knapsack is best supported. The old fashion of carrying the military knapsack entirely upon the shoulder and fixing it by cross-belts over the chest, undoubtedly compressed the thorax, hampered the breathing, and produced irritation of the heart.

Straps passing from the top of the knapsack over the shoulders and then returning to the bottom of the knapsack by bending round the armpits are found to be practically serviceable, and they keep the knapsack steady both for quick and slow time of march and in going up or down hill.

A very excellent form of knapsack is one consisting of two bags, of which one lies against the upper dorsal region, and the other in the hollow of the loins. They are united by straps passing from the top of the upper bag over the shoulders and then obliquely downwards in the axillary region to the top of the second bag. These bags are then supported partly on the shoulders and partly on the sacrum, and as one bag balances the other the weight is well divided. The only drawback is their tendency to bump about when the traveller is coming downhill, a tendency which is easily checked by stays passing to a waist-belt.

A few words may be said with advantage on the æsthetic aspects of dress, although it is true that there is no possibility of disputing about matters of taste. There seem to be some few principles, however, which form the true groundwork of the question, which it may be well to discuss.

In the first place a dress must suggest cleanliness and purity. If we place side by side in the mind's eye the modern nurse or dairymaid in clean print dress and spotless cap and apron and the costermonger's girl bedecked in tawdry finery, there can be no question as to which is most pleasing to the educated eye. No costume can really look well if it be not kept clean, and directly a dress suggests anything but the most perfect cleanliness its æsthetic value becomes nil.

The working classes in this country dress very largely in the cast-off

clothing of the class above them, and persons who are too poor to keep a lady's maid are fond of imitating the costumes of those who do, with the result that such costumes are never properly cleaned and brushed; an operation which the owner, who probably has many duties, has not time to perform. The working classes in this country seldom wear a blouse, as the French do, and the smock frock has been almost completely abandoned, with the result that a large proportion of the labouring classes look habitually filthy. It is absolutely essential from the æsthetic and hygienic point of view that the outer clothes of people who work for their living should be made of washable materials with a smooth surface. Domestic servants very generally follow this rule, but among the working classes at large the painters are almost the only section who habitually wear washable overalls.

The dressing of the hair should be of a fashion to suggest cleanliness. Tumbled hair may be 'artistic,' but it suggests dust and a difficulty of combing which is not quite comfortable for the thoughtful onlooker. Truly artistic clothing must suggest health and comfort. It must not be tight, nor must the folds be so cumbersome as to hamper free movement. It must be suitable for the climate and season. All attempts to adopt 'classic styles,' i.e. the costume once worn in Athens, which is fifteen degrees south of London, must end in failure.

On the question of colours we have little to say except that the dowdy half-tints which were in vogue a few years since, in so much as they suggested fading and shabbiness, seemed to fail in the first law of æstheticism. The colour should certainly vary with the season—cool light colours for the summer and 'warm' tints for the winter.

It will probably be useful to give as an appendix to this article a few receipts which will be found serviceable in connection with clothing. These have been taken from the sixth edition of Cooley's 'Cyclopædia of Practical Receipts,' edited by R. V. Tuson (London: J. and A. Churchill).

Waterproofing.—1. Moisten the cloth on the wrong side first with a weak solution of isinglass, and, when dry, with an infusion of nut-galls.

2. Moisten the cloth on the wrong side first with a solution of soap, and, when dry, with a solution of alum.

3. Rub the wrong side of the cloth with a lump of beeswax (perfectly pure and free from grease) until it presents a light but even white or greyish appearance; a hot iron is then to be passed over it, and, the cloth being brushed whilst warm, the process is complete. When the operation has been skilfully performed a candle may be blown out through the cloth if coarse, and yet a piece of the same, placed across an inverted hat, may have several glassfuls of water poured into the hollow formed by it without any of the liquid passing through.

Waterproof liquids, for boots, shoes, and leather articles.

1. India-rubber in fragments, 1 oz.: boiled oil, 1 pint; dissolve by heat, carefully applied, then stir in of hot boiled oil 1 pint, and remove the vessel from the fire.

2. Boiled oil, 1 pint; beeswax and yellow resin, of each 2 oz.; melt them together.

Dubbing.—Black resin, 2 lb.; tallow, 1 lb.; crude cod oil or train oil, 1 gallon; boil to a proper consistence.

Stains and spots on clothes may be removed with a little clean oil of turpentine or benzol, or with a little fuller's earth or scraped French chalk made into a paste with water and allowed to dry on them, or by a hot flat-iron and a piece of blotting-paper.

Fruit and wine stains on linen commonly yield easily to hot soap-and-water.

Ink spots and recent iron mould on washable fabrics may be removed by dropping on the part a little melted tallow from a common candle before washing the articles, or by the application of a little lemon juice or powdered cream of tartar made into a paste with hot water.

Old ink spots and iron mould will be found to yield almost immediately to a very little powdered oxalic acid, which must be well rubbed upon the spot previously moistened with boiling water and kept hot over a basin filled with the same.

Fireproofing.—It is very advisable to treat light, gauzy articles (such as muslin) in some way to prevent them from flaring up if they come accidentally in contact with a light. This may be attained by steeping the fabric in almost any saline solution. Thus, cotton or linen stuffs, prepared with a solution of borax, phosphate of soda, phosphate of ammonia, alum, or sal-ammoniac, may be placed in contact with ignited bodies without their suffering active combustion or bursting into flame. The salts act by forming a crust of incombustible matter on the surface of the fibres.

The addition of about 1 oz. of alum or sal-ammoniac to the last water used to rinse a lady's dress, or a set of bed furniture, or a less quantity added to the starch used to stiffen, renders them uninflammable, or at least so little combustible that they will not blaze.

For fine muslin, *tungstate of soda* is found to answer better than any of the above-named salts. 'Muslin steeped in a solution containing 20 per cent. of this salt is perfectly non-inflammable when dry, and the saline film left on the surface is smooth and of a fatty appearance like talc, and therefore does not interfere with the process of ironing, but allows the hot iron to pass smoothly over the surface. The non-fulfilment of this latter condition completely prevents the use of many other salts, such as sulphate or phosphate of ammonia, which are otherwise efficacious in destroying inflammability—for all fabrics which have to be washed and ironed' (Watts).

Reference to Plate of Fibres

A. *Linen* (Linen handkerchief). B. *Cotton* (Sewing cotton). C. *Silk* (Silkworm cocoon). D. *Wool* (Woollen shawl). E. *Hemp* (Rope). F. *Coir* (Cocoa-nut matting). G. *Jute* (The raw material). H. *Fur* (Rabbit).

(*a*) *Low power* (about 100 diameters). (*b*) (*c*) *High power* (about 500 diameters). In G, (*b*) represents a small bundle, (*c*) a single fibre.

PHYSICAL EDUCATION

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INTRODUCTORY

Writers are not yet weary of enlarging upon the marvels of civilisation, upon the intellectual development of the human race, upon the triumphs of human ingenuity, and the might and magnificence of human culture. He has, indeed, much to marvel at who measures the gulf which separates the polished citizen of the world from the half-naked and quite savage barbarian. The inventive genius of the modern, the high development of each craft and industry which he has cultivated, the skill of the nineteenth-century artisan, the general intellectual condition of the masses in the great centres of civilisation, are all features of attraction for those who are unceasing in the glorification of the race. The great elements in human progress afford, indeed, proper material for admiration. There is no one but would admit that the advantages of the civilised man over the savage are such as to make reasonable comparisons scarcely possible; but there follows upon this the question as to whether the so-called blessings of civilisation represent an unmixed good. The intellectual victory has been great, but it has not been effected without cost. We have in our midst the inventor, the man of genius, the handicraftsman, but we have also the weakling, the delicate, the misshapen, and that most modern product of all, the mannikin of the city. This pale, wizened, undersized creature represents no little sacrifice; he is a product of civilisation, an unintentional manifestation, but a characteristic one.

If one watches the stream of men, boys, and girls which pours out at the close of day from a great city factory, the question may well be asked, Are these superior to the savage in all things, and are there no points in which the barbarian could claim some advantage over his modern descendant?

The savage Norseman who first sailed the northern seas knew little of art and less of science, but he had great lungs and a stout heart and mighty muscles and exhaustless strength, and was a stranger—it might be assumed—to many of the aches and pains and petty illnesses which the modern town dweller regards as a natural heritage.

In the face of a marvellous social, moral, and intellectual development we are apt to lose sight of the fact that man is an animal, that he cannot yet do without a body, and that a strong receptacle for the mind is better than a frail one.

The higher type of savage was perfect in form, lithe in movement, keen of vision, and strong of arm. He felt in his veins the glow of life, the joy of mere vigour thrilled his muscles, the instincts of mere health dignified his movements. If he pursued physical culture to an exclusive degree, it is possible that his civilised brother may carry intellectual finish to an equal extreme.

There is evidence to show that an exclusive development of what are quite properly termed the higher faculties of man is not of unmixed advantage. Progress is so rapid, and the movements of daily life are so exacting, that there is a tendency to overlook the fact that man cannot live by intellectual bread alone. The young lad is taught to read as soon as he can lisp, and to write as soon as he can grasp a pen. At school he is forced and fostered like a hot-house plant, and when he is old enough to

take his place in the race in life he at once feels the fever of competition and the strain of incessant endeavour.

It is, however, becoming obvious that one great element of success in life is bodily strength; and that he who has every mental requirement and the finest intellectual finish may find that he still lacks the one thing needed. Sound physical health enables a man to work with vigour and freshness, to pass unharmed through periods of unusual pressure, to withstand the evils of worry, to preserve a clearness and acuteness of mind when others are worn and fretful and uncertain, and to still press forward when others have fallen in the race.

He will do well who still retains in the midst of his city life some of the qualities of the men of the plain. He will find that muscular strength and good lungs are not without value, even though he be no longer dependent upon the hunter's skill for his daily meal. The attributes of the trapper and the seaman are attributes which cannot be without service, even in the murkiest life in the wilderness of a great city.

It is now more or less clearly recognised that no skill, no learning, no intellectual greatness, can carry with it its fullest influence without a certain element of physical capacity in the individual.

The unduly diligent student who burns the midnight oil, who cannot tear himself away from his books, who moves in a world in which the only sunshine is that of learning, and the only breeze is that which blows from the erudition of the past, is often a miserable object enough as a human being. His face is wan, his arms are feeble, his eyes are dim, he lives in an atmosphere of little ailments, and he has few pleasures other than the joys of the bookworm. Such a man would make no less progress in the present, and would effect no less influence in the future, if he would devote some leisure to the cultivation of his body. A clear eye, a wiry limb, and a ruddy cheek are not inconsistent with the greatest intellectual development; while on the other hand there are many poor lads who have been crammed and cultivated until they are mere learned invalids. It may well be asked of their learning, 'What will they do with it?' Many a 'city man' can have but little knowledge of living, however much he may know of 'life.' His hurried hours of work are followed by a period of dulled rest. He lives in the maze caused by the rush of passing events, he knows little of the joys of the world as the barbarian knows them, and his journey through life is but at a halting and creaking pace. He remains a partly developed creature who has never attained to the full stature of a man.

Montaigne well says, in speaking of a man as he should be, 'I would have the disposition of his limbs formed at the same time with his mind. 'Tis not a soul, 'tis not a body we are training, but a man, and we must not divide him.'

In certain directions the importance of simple physical health and strength cannot well be exaggerated. The part these have played in the history of the British race has been magnificent enough. The glories of English enterprise, the daring and hardihood of the British seaman, the unconquerable pluck of the English soldier, have taken no little share in forming the greatness of the British nation. The love of sport among the English, the delight in manly games and outdoor exercises, the contempt for what is effeminate and feeble, are outcomes of a vigorous health and a sturdy growth.

There is no need to modify the fact that the position of Great Britain among European nations is due in no small extent to qualifications which have been the glory of savage peoples. The explorer may have profound knowledge and a preternatural judgment, but they avail but little if he be

not possessed of mere rude health and strength. The main pride of the early navigator was his reckless courage and his sturdy endurance. The greatest commander would have proved a man of straw had he not at his call men who shirked no hardship and who felt no fear.

It may not be a graceful acknowledgment, but it is none the less true that the power of the English people has depended in no little degree upon those very humble qualities which make 'a good animal.'

There is an instinct which impels the human being to seek health in muscular exercise and pleasure in physical exertion. The very restlessness of the child is an expression of this. It is often said of a child that he or she is never still. It is an excellent feature. It is as unreasonable to expect a young lad to keep quiet as to expect him not to cough when he has a cold. The infant jumps and kicks and crows; the child shows its natural promptings by incessant restlessness. The schoolboy, if he be vigorous and healthy, appears to have acquired the art of perpetual movement. The mad rush of a crowd of schoolboys from the schoolroom the moment they are free is characteristic enough and pleasant to witness. The limbs and muscles which have been so long still feel the need of movement as a half suffocated man feels the need of air. The boy who is the first to reach the open air beyond the schoolhouse door has probably not an evil future before him; he has at least made a good beginning. He, on the other hand, who crawls out last, who feels no irresistible impulse to jump and shout, is in some way abnormal; he is ill in health or imperfect in construction. He may prove an excellent scholar, but the terrible earnestness of the race of life is not best met by mere scholarship.

Throughout life there exists in all healthy bodies this natural craving for exercise, and a man may consider that he has reached an unfortunate period in his career when he has ceased to feel that impulse.

Muscles can grow only by exercise and by the simple expedient of using them. The disused muscle wastes, and becomes fatty and anæmic. Muscular tissue occupies nearly every part of the body, from so delicate a piece of mechanism as the eye to so simple a structure as the biceps humeri. Exercise implies not merely the development of the muscles of the limbs, it implies also the healthy use of the muscle of the heart, of the muscles of respiration, of the muscular tissue of the arteries, and of the muscular elements of all parts capable of movement. Such movement carries with it of necessity an activity in the nervous system, an activity in the secreting organs and in the organs of excretion.

Movement, indeed, within proper bounds is essential to the full development and perfect maintenance of the health of the body. The body is a machine with the peculiar attribute that the more it is used, within reasonable limits, the stronger and more capable it becomes. It gathers strength by movement, and that strength is to be gauged, not by mere muscular force, but by the perfect functional condition of every part and of every organ.

Physical Education involves exercise and movement. We know of no other means of developing any portion of the organism, provided that the supply of food and of air be sufficient. Exercise means growth, functional vigour, and the maintenance of a high standard of organic life. Undue rest implies decay, feebleness, and a debased standard of functional value. Absolute rest is found only in death.

Of artificial means of attaining physical perfection there are none. Every structure and tissue must be duly and accurately exercised and kept in proper movement; and this applies as well to the ciliary muscle of the eye as it does to the great flexors of the leg, as well to the peptic glands of the

stomach as to the cells of the cortex of the brain. The body is like a busy town; so long as there is activity within its walls, and so long as every nook and corner is alive with the best energies of those who dwell therein, things fare well; but when one section flags, when inactivity falls upon this quarter or upon that, there comes some retrogression, some halting in a progress which had hitherto been even and energetic. If the intellect is to be cultivated, the brain must be exercised. He who wishes to acquire the far vision of the seaman must use his eyes like a seaman, and he who would develop the hunter's keenness of hearing and powers of endurance must lead the hunter's life.

To learn how to rightly exercise every part and organ of the body, and how to effect this without undue effort or injurious strain, is to discover the elixir of life and such a philosopher's stone as will render the short tenure of human life as free from bodily troubles as the art of man can make it.

It is no longer possible to say, as Herbert Spencer did some twenty years ago, that the inhabitants of this country take an interest in the rearing of the offspring of all creatures except themselves. Civilisation has not yet greatly impaired the unconquerable love of sport and the passion for movement and violent exercise which appear to be the heritage of the British race. There is some evidence to show that, taking averages, we have not diminished either in height or in girth. There is evidence of deterioration among the poorer inhabitants of great cities, but among the more favoured classes it would appear that no change has taken place which indicates a distinct downward tendency. Within recent years there has been a remarkable revival of interest in sports, games, and athletic exercises of all kinds. It was not until 1875 that the English Channel was crossed by a swimmer. So far as it is known, it was not until the year 1877 that a human being had ever leapt from the ground, without artificial aid, to the height of 6 feet 2 inches. A man can now jump across a gap 23 feet in width, a mile has been run in less than $4\frac{1}{2}$ minutes, and 600 miles have been walked in one week.

It is quite obvious that the term Physical Education must include the regulation of the functions and movements of the entire body. With such as concern the supply of suitable food and wholesome air, and the observation of what are known as simple hygienic conditions, the present paper has no concern.

It is necessary here to deal only with that most conspicuous factor in physical culture which concerns the due and proportionate exercise of the muscles of the body.

In the following article we shall first consider the general effects of exercise, including the subjects of fatigue, overwork, and want of exercise, and secondly the effects of specific exercises.

THE GENERAL EFFECTS OF EXERCISE

1. The Effect of Exercise upon the Development and Proportions of the Body

Exercise, as here understood, may be represented by such natural, systematic, and well-regulated exercises as enter into the life of every healthy public schoolboy, together with such special gymnastics which may be considered to be necessary in particular cases. It must be understood that the object of exercise—as here intended—is not to develop athletes, acrobats, and

phenomenally strong men, but to encourage and maintain the highest and most equable development of the body.

The secret of the size and proportions of the future man lies buried in the ovum from which the individual is developed. It may be said, indeed, that there are two proportions possible in every human body—first, that which is congenital, inherited, and predetermined; and, secondly, such an increase or modification of these proportions as may be effected by proper exercise.

The child of short and stunted parents will probably also be short and stunted, and may remain so in spite of an elaborate physical training. An infant Bushman transformed suddenly to a cotter's home in Scotland could never be expected to attain the proportions of the young Highlanders with whom his lot had been cast. In estimating the effect of exercise and in speculating upon its possible powers in this direction a constant reference must be made to those inherited factors which are quite beyond control. Exercise cannot make a man a giant, nor can it with any certainty develop a modern Hercules. It can, however, influence the growth and structural perfection of the body in a manner which is definite and to some extent remarkable.

Exercise increases the size of a muscle, the proportions of its tendon and the power it can command. After undue rest a muscle becomes thin, soft, wasted, and feeble. The stronger the muscles, the finer and denser are the aponeuroses with which they are connected and the stouter are the fasciæ which hold them in position. Muscles act upon articulations. The duly exercised joint has a good covering of cartilage, powerful ligaments, and well-developed bony parts. The joint which has been long kept at rest has wasted ligaments, a thinned cartilage, and bones of smaller proportions. It becomes, moreover, hyperæsthetic from disuse, and the tissues around are found to be flabby and anæmic. Within certain somewhat narrow limits the mechanical possibilities of a joint can be much extended by exercise.

Muscular strength, moreover, influences the size of the bones upon which the muscles act. The skeleton of a feeble individual compares in a very marked manner with the skeleton of a muscular person of the same height and the same age. The bone of the muscular individual is stronger, firmer, and denser; it is actually larger, and the so-called muscular surfaces and ridges are more conspicuously marked.

Exercise induces a more vigorous respiration, and under increased breathing efforts the lung capacity is increased and the size of the thorax is augmented. Exercise, moreover, accelerates the blood circulation, and it is needless to point out the effect an increased blood supply has upon the size and development of the tissues concerned.

1. *The Development of the Body.*—Before considering the special effects of exercise upon the growth of the body it is necessary to take note of what may be termed the average measurements of the human organism.

The principal facts with regard to the growth of the body, its weight and height at various periods of life, its comparative proportions in males and females, and other features concerned in Anthropometry, are briefly set forth in the following tables.

The principal tables are derived from Mr. Charles Roberts's 'Manual of Anthropometry,' and to this admirable and classical work the reader is referred for more extensive details. Much use has been made also of the Report of the Anthropometric Committee of the British Association, 1882–3. This report was drawn up by Mr. Roberts and Sir R. W. Rawson, and has been published as an appendix to Mr. Roberts's 'Manual.' These two works provide

the most precise data upon Anthropometry, so far as the English race is concerned, which we possess.

It may in the first place be well to tabulate the periods at which the various parts of the skeleton are completed, so far as the facts of osteology guide us.

The Spine	The 25th year
The Pelvis	The 25th year
The Shoulder Girdle	The 25th year
The Upper Limb.	The 20th year
The Lower Limb	The Femur the 20th year The Tibia the 22nd year The Fibula the 24th year

Table I.—*Showing the average* stature (*without shoes*) *and the average* weight (*including clothes*) *at all ages of the general population of Great Britain.* (*All classes. Town and country.*) Number of observations on which the averages are founded. *Stature:* Males, 37,574. Females, 4,616. *Weight*: Males, 33,043. Females, 4,685. (From the Report of the Anthropometric Committee, 1883.)

Males					Females				
Age last birthday	Average height, inches	Increase in inches	Average weight, pounds	Increase in pounds	Age last birthday	Average height, inches	Increase in inches	Average weight, pounds	Increase in pounds
Birth	19·52	—	7·1	—	Birth	19·31	—	6·9	—
0–1	27·00	—	—	—	0–1	24·83	5·52	—	—
1	33·50	—	—	—	1	27·50	2·67	20·1	—
2	33·70	—	32·5	—	2	32·33	4·83	25·3	5·2
3	36·82	—	34·0	1·5	3	36·23	3·90	31·6	6·3
4	38·46	1·64	37·3	3·3	4	38·26	2·03	36·1	4·5
5	41·03	2·57	39·9	2·6	5	40·55	2·29	39·2	3·1
6	44·00	2·97	44·4	4·5	6	42·88	2·33	41·7	2·5
7	45·97	1·97	49·7	5·3	7	44·45	1·57	47·5	5·8
8	47·05	1·08	54·9	5·2	8	46·60	2·15	52·1	4·6
9	49·70	2·65	60·4	5·5	9	48·73	2·13	55·5	3·4
10	51·84	2·14	67·5	7·1	10	51·05	2·32	62·0	6·5
11	53·50	1·66	72·0	4·5	11	53·10	2·05	68·1	6·1
12	54·99	1·49	76·7	4·7	12	55·66	2·56	76·4	8·3
13	56·91	1·92	82·6	5·9	13	57·77	2·11	87·2	10·8
14	59·33	2·42	92·0	9·4	14	59·80	2·03	96·7	9·5
15	62·24	2 91	102·7	10·7	15	60·93	1·13	106·3	9·6
16	64·31	2·07	119·0	16·3	16	61·75	·82	113·1	6·8
17	66·24	1·93	130·9	11·9	17	62·52	·77	115·5	2·4
18	66·96	·72	137·4	6·5	18	62·44	—	121·1	5·6
19	67·29	·33	139·6	2·2	19	62·75	·23	123·8	2·7
20	67·52	·23	143·3	3·7	20	62·98	·23	123·4	·6
21	67·63	·11	145·2	1·9	21	63·03	·05	121·8	—
22	67·68	·05	146·9	1·7	22	62·87	—	123·4	—
23	67·48	—	147·8	·9	23	63·01	—	124·1	·7
24	67·73	·05	148·0	·2	24	62·70	—	120·8	—
25–30	67·80	·07	152·3	4·3	25–30	62·02	—	120·0	—
30–35	68·00	·20	159·8	7·5	30–35		—	120·8	—
35–40	68·00	—	164·3	4·5	35–40		—	120·8	—
40–50	67·96	—	163·3	—	40–50	61·15	—	118·0	—
50–60	67·92	—	166·1	1·8	50–60		—	104·0	—
60–70	67·41	—	158·1	2·0	60–70		—	—	—
70	69·22	1·22	182·1	—	70		—	106·0	—

The following comments upon the series of tables of which the above is an abstract are furnished by the Anthropometric Committee :—

1. Growth is most rapid during the first five years of life.

2. From birth to the age of five years the rate of growth is the same in both sexes, girls being a little shorter in stature and lighter in weight than boys.

3. From five to ten years boys grow a little more rapidly than girls, the difference being apparently due to a check in the growth of girls at these ages.

4. From ten to fifteen years girls grow more rapidly than boys, and at the ages of eleven and a half to fourteen and a half are actually taller, and from twelve and a half to fifteen and a half years actually heavier than boys. This difference appears to be due to a check in the growth of boys as well as an acceleration in the growth of girls incident on the accession of puberty.

5. From fifteen to twenty years boys again take the lead, and grow at first rapidly, then gradually slower, and complete their growth at about twenty-three years. After fifteen, girls grow very slowly, and attain their full stature about the twentieth year.

6. The tables show a slow but steady increase in stature up to the fiftieth year, and a more rapid increase in weight up to the sixtieth year in males, but the statistics of females are too few after the age of twenty-three to determine the stature and weight of that sex at the more advanced periods of life.

'It is probably due to the greater or less development of the body at the time of the accession of puberty,' writes Mr. Roberts, 'that the final difference in the height of individuals is chiefly to be attributed; hence the influences which promote or retard growth at this period are most deserving of study. In boys puberty occurs later, and is less regular and decided, than in girls. The transition from boyhood to manhood extends over a period of three to four years, and is accompanied by increased physical development of the body; but girls develop into women in a few months, and with the complete establishment of puberty, growth in height is much diminished, and often ceases altogether.'

As a further contribution to the subject of the growth of boys the following tables compiled by Maclaren may be added:—

Table II.—*Showing the State of Growth and Development between the ages of* 10 *and* 18 *years, being the* averages *of the actual measurements of* 100 *boys* at each age. (*Maclaren*)

Age	Height		Weight		Girth of chest	Forearm	Upper arm
Years	Ft.	in.	St.	lb.	Inches	Inches	Inches
10	4	5½	4	9	25¼	7½	7¾
11	4	7	5	0	26¼	7¾	8
12	4	8¾	5	8¼	27½	8	8¼
13	4	10½	6	0¼	28½	8¼	8½
14	5	0¾	6	9	29½	8½	9
15	5	3	7	5½	30¾	9	9½
16	5	5	8	4½	32½	9½	10¼
17	5	7	9	2½	34¼	10	11
18	5	8	9	11	35¼	10¼	11¼

Table III.—*Abstract of preceding Table showing average Annual Rate of Growth and Development from year to year.* (*Maclaren*)

—	Height	Weight	Girth of chest	Forearm	Upper arm
	Inches	Lb.	Inches	Inches	Inches
From 10 years to 11 years . . .	1½	5	1	¼	¼
„ 11 „ 12 „ . . .	2	8¼	1¼	¼	¼
„ 12 „ 13 „ . . .	1¾	6	1	¼	¼
„ 13 „ 14 „ . . .	2¼	8¾	1	¼	½
„ 14 „ 15 „ . . .	2¼	10½	1¼	½	½
„ 15 „ 16 „ . . .	2	13	1¾	½	¾
„ 16 „ 17 „ . . .	2	12	1¾	½	¾
„ 17 „ 18 „ . . .	1	8½	1	¼	¼

Some children appear to grow by fits and starts. Children who have remained for many successive years under the average height may suddenly shoot up and attain more than the normal stature when they reach adult age. (See in connection with this matter Case 4, Table VII.)

The extremes in development are well illustrated by the following observations made by Maclaren. They give the result of the examination of 100 University men (freshmen) who were not especially selected.

	The greatest developments	The smallest developments
Height	6 ft. 6 in.	5 ft. 2 in.
Weight	12 st. 2 lb.	7 st.
Chest girth	39 in.	$27\frac{1}{4}$ in.
Forearm	$11\frac{3}{4}$ in.	$8\frac{1}{2}$ in.
Upper arm	$12\frac{3}{4}$ in.	$8\frac{3}{4}$ in.

The effect of occupation and social and physical condition upon development is well demonstrated by the statistics prepared by Mr. Roberts and the Anthropometric Committee.

The following tables are derived (in abstract) from the Report of the Committee :—

Table IV.—*Relative Height of Boys at the age of* 11 *to* 12 *years under different social and physical conditions of life.*

	Average height
Public schools (country)	54·98 inches
Middle-class schools :	
Upper (towns)	53·85 ,,
Lower (towns)	53·70 ,,
Elementary schools :	
Agricultural labourers	53·01 ,,
Artisans (town)	52·60 ,,
Factory hands (country)	52·17 ,,
Factory hands (towns)	51·56 ,,
Military asylums	51·20 ,,
Industrial schools	50·02 ,,

Table V.—*Relative Height of Adults of the ages from* 25 *to* 30 *years under different social and physical conditions of life.*

	Average height
Upper classes, professional classes	69·14 inches
Commercial classes, clerks, shopkeepers, &c.	67·95 ,,
Agricultural labourers, miners, sailors, &c.	67·51 ,,
Artisan classes (towns)	66·61 ,,
Factory hands, workers at sedentary trades—e.g. tailors	65·92 ,,

The question of the relation of weight to height will be found considered in Table I.

Table VI. gives the average chest-girth in males at different periods of life (see also Tables II. and III.). The chest-girth in males shows an increase at a rate similar to that of the weight up to the age of fifty years, but it appears to have no definite relation to stature.

Table VI.—*Average Chest-girth (empty) in inches in Males of all classes at different ages (Report of Anthropometric Committee).*

Age next birthday	Chest girth in inches	Age next birthday	Chest girth in inches	Age next birthday	Chest girth in inches
10	26·10	16	31·53	22	35·33
11	26·53	17	33·64	23	35·62
12	27·20	18	34·19	24	35·82
13	28·03	19	34·49	25–29	36·18
14	28·46	20	34·98	30–35	37·08
15	29·74	21	35·25	36–50	37·58

The effect of systematised exercise upon the growth and development of boys and men may now be considered. In the Report of the Anthropometric Committee the measurements of eighty-nine professional and amateur athletes are given with the following results. 'Their average stature exceeds that of the general population from which they are drawn by 0·68 inch, while their average weight falls short of that standard by 14·5 lb. The ratio of weight to stature is in the athletes 2·100 lb. and in the general population 2·323 lb. for each inch of stature. Thus a trained athlete whose stature is 5 feet 7 inches should weigh 10 stone, while an untrained man of the same height should weigh 11 stone.'

TABLE VII.—*To show the Effects of Systematised Exercise upon growth and development (Maclaren).*

—			Measurements, &c.					Increase					Remarks
Case	Date	Years	Height	Weight	Chest	Fore-arm	Upper arm	Height	Weight	Chest	Fore-arm	Upper arm	
			Ft. in.	St. lb.	In.	In.	In.	In.	Lb.	In.	In.	In.	
1	1861 June	10	4 6¾	4 10	26	7¼	7½						Height *above* average. Other measurements, average. From commencement, growth rapid and sustained, with regular and uniform development.
	1862 Sept.	11	4 9½	5 5	28½	8½	8½	2¾	9	2½	1¼	1	
	1863 Sept.	12	4 10¾	6 0	30½	8½	8⅞	1¼	9	2	—	⅜	
	1864 June	13	5 2¼	7 2	32½	9⅜	9⅞	3½	16	2	⅞	1	
	1865 May	14	5 5⅞	8 3	35½	9¾	10¼	3⅝	15	3	⅜	⅜	
	1866 May	15	5 9	10 2	37½	11	12	3⅛	27	2	1¼	1¾	
	1867 Sept.	16	5 9½	10 13	38½	11⅛	12⅜	½	11	1	⅛	⅜	
	1868 Sept.	17	5 10¾	11 2	39½	11¾	13⅜	1¼	3	1	⅝	1	
							Total increase .	16	90	13½	4½	5⅞	
2	1860 Jan.	12	4 1⅞	3 13	23½	6½	6						Height and all other measurements greatly *below* average. Whole frame stunted and dwarfish. Advancement at first slight and very irregular, afterwards rapid and comparatively regular.
	1860 July	12	4 3¾	4 0	24	7	6¾	1⅞	1	½	½	¾	
	1860 Dec.	13	4 4½	4 1	24½	7	7	¾	1	½	—	¼	
	1861 Dec.	14	4 4½	4 7	25	7¼	7¼	—	6	½	¼	¼	
	1862 July	14	4 5⅜	4 8	26	7½	7½	⅞	1	1	¼	¼	
	1863 Mar.	15	4 7¼	4 12	26½	7⅝	7⅝	1⅞	4	½	⅛	⅛	
	1864 July	16	4 11¼	6 6	29½	8⅝	8¾	4	22	3	1	1⅛	
							Total increase .	9⅜	35	6	2⅛	2¾	
3	1859 Dec.	14	4 5	6 1	26½	8	7¾						Height greatly below average; other measurements also considerably below average. Instant and extreme acceleration of growth with moderate increase in development.
	1860 Sept.	14	5 2	6 4	29	9	9½	11	3	2½	1	1¾	
	1861 July	15	5 4½	7 7	30	9	9½	2½	17	1	—	—	
	1862 Sept.	15	5 7¼	8 12	34½	10	11¼	2¾	19	4½	1	1¾	
							Total increase .	16¼	39	8	2	3½	
4	1859 Oct.	19	5 2⅝	8 0	30½	9	9½						Well proportioned. A remarkable feature is the renewal and steady continuation of the upward growth which had been prematurely arrested.
	1859 Dec.	—	5 3¼	8 1	33	9½	10¼	⅝	1	2½	½	¾	
			5 3⅝	8 1	33	9½	10¼	⅜	—	—	—	—	
	1860 Jan.	20									lost		
	— —	—	5 4⅛	8 1	33½	9¼	10¼	½	—	½	¼	—	
	— June	—	5 4⅝	8 3	34	9¼	10¼	½	2	½	—	—	
	— —	—	5 4⅝	8 5	34¼	9½	10½	—	2	¼	¼	¼	
							Total increase .	2	5	3¾	½	1	
5	1859 Oct.	17	6 0	9 4	30½	8¾	9¼						Of delicate frame: chest flat and narrow, with sternum much depressed.
	1860 Jan.	17	6 0	9 9	32½	9¼	10	—	5	2	½	¾	
	1860 June	18	6 0½	9 11½	34	9¾	10¼	½	2½	1½	½	¼	
	1860 June	18	6 0½	9 13	34½	9¾	10½	—	1½	½	—	¼	
							Total increase .	½	9	4	1	1¼	

This question of the effect of systematic exercise upon development has been fully dealt with by Mr. Maclaren.

His tables dealing with the subject are of great value, and should be consulted by all those who are interested in the matter. In the appended tables a selection from these statistics is given. The normal increase in height and weight, as given in Table I., must be taken into consideration.

TABLE VIII.—*Measurements of twelve Non-commissioned Officers (selected to be qualified as Military Gymnastic Instructors after eight months' training.* (*Maclaren.*)

Increase noted at end of period					
Age	Height	Weight	Girth of chest	Forearm	Upper arm
Years	In.	Lb.	In.	In.	In.
19	$\frac{3}{8}$	13	$4\frac{1}{2}$	1	$1\frac{3}{4}$
21	$\frac{1}{4}$	10	$3\frac{3}{4}$	1	$1\frac{1}{4}$
23	$\frac{3}{4}$	9	$3\frac{1}{2}$	1	$1\frac{1}{4}$
23	$\frac{1}{2}$	9	$1\frac{1}{2}$	$1\frac{1}{4}$	1
23	$\frac{1}{4}$	10	1	$\frac{1}{2}$	1
23	$\frac{1}{8}$	9	2	$\frac{1}{2}$	1
23	$\frac{1}{8}$	5	$2\frac{1}{2}$	$\frac{1}{4}$	1
24	$\frac{1}{2}$	12	5	1	$1\frac{1}{4}$
26	$\frac{5}{8}$	$6\frac{1}{2}$	3	$\frac{1}{4}$	$1\frac{1}{4}$
$26\frac{3}{4}$	$\frac{3}{8}$	9	1	—	1
28	$\frac{1}{2}$	13	3	$1\frac{1}{4}$	$1\frac{1}{4}$
28	$\frac{1}{8}$	16	3	$1\frac{1}{4}$	1

In an examination of Tables VII. and VIII. the increase in weight under systematised exercise, after allowing for normal increase, is noteworthy.

In the matter of increase in growth Case 4, Table VII., is interesting as showing the renewal of growth after premature arrest, the young man growing 2 inches after nineteen. Mr. Maclaren gives several other instances of this sudden growth after premature arrest. In Table VII. the increase in height of the older men in the list is of interest. In the majority it may be due to a greater erectness of the figure, to the lessening, therefore, of some of the curvature of the spine, and perhaps to some increase in the intervertebral substances.

In the case of the soldiers in Table VIII. the question of the improvement of the carriage can scarcely come into consideration, and the increase in height from $\frac{1}{8}$th to $\frac{5}{8}$ths of an inch in the last four men must be ascribed to changes in the tissues. In Case 3, Table VII., the immediate effect of systematised exercise is apparently shown by a remarkable increase in height of no less than 11 inches in a period of nine months.

A further point in these tables must be noticed, and that is the remarkable increase in the circumference of the chest, which, it would appear, may be obtained by systematic exercise.

An increase of 3 to 4 inches in the girth of the thorax may no doubt be in great part ascribed to muscular development in the pectoral and scapular regions. It involves, however, an increased respiratory power, and a greater breathing capacity.

In a country where lung diseases are so common as they are in England, it is difficult to speak too strongly of the importance of obtaining a full development of the chest.

Physicians recognise the part played by a narrow thorax and a feeble breathing power in aiding the evolution of chronic lung disease and in promoting the progress of such processes as are acute.

Considering the definite and apparently assured results of physical training in this direction, it appears culpable to allow a child to grow up surrounded by the undoubted dangers which attend the possession of a constricted chest.

It will be observed from the above tables that a great increase in the circumference of the chest can take place as an almost solitary feature of development. Mr. Maclaren gives the case of a lad of nineteen whose height was not increased by systematic exercise, but who increased the girth of his chest by $4\frac{1}{2}$ inches in nine months.

It is well also to note that an improvement in the measurements of the chest can be effected many years after the period of youth is passed. Thus Maclaren cites the case of a gentleman aged thirty-five who at the end of two months' exercise at the Oxford Gymnasium had increased the circumference of his thorax by no less than $4\frac{1}{2}$ inches. His height was diminished by an eighth of an inch, due probably to an increase in the curvature of the thoracic part of the spine.

In considering the general question of increase in chest girth care must be taken not to ascribe this increase—as some appear inclined to do—entirely to an increase in the capacity of the thoracic cavity. This is probably in all cases of much less effect than muscular development. Those who practise excessively with gymnastic apparatus acquire a peculiar conformation of the chest, the main factor in which is certainly not an increase in the capacity of the thorax.

2. *The Proportions of the Body.*—A proper physical training does something more than merely increase the size of the limbs and possibly the height of the body. It tends to render all parts of the body symmetrical and more perfectly proportioned.

A well-proportioned body has a grace which is independent of mere size, height, and strength. It is in women especially that the great lack of a perfect proportion is so often conspicuous. In one the hips are out of proportion to the shoulders; in another the width of the chest is totally out of keeping with the height of the body; in a third the length of the upper limbs is not in proportion to the dimensions of the trunk.

Those who have taken properly arranged exercise from their earliest youth may still need many graces, but they will probably possess the peculiar grace which belongs to a symmetrical body.

Of all animals man is the most subject to variations in proportion and in symmetry. It is certain that in some children the body develops unevenly: one side appears to be larger than the other; one limb may be longer than its fellow; one side of the thorax may be of greater circumference than the other. Such deviations—which in no sense constitute deformity—a well-directed system of physical training may correct.

It is common to meet a long, lanky lad with spider-like arms and legs, a meagre neck, and a narrow chest. It is probably said that he has 'outgrown his strength.' In reality his growth in height has been out of proportion to his growth in muscular power. With proper training such a lad ceases to be lanky; he becomes merely tall, his chest fills out, his arms acquire a greater girth, his neck becomes sinewy, and the 'scarecrow' of the schoolroom becomes possibly a lithe, well-proportioned youth.

Another lad may be squat and 'stumpy' and heavy-looking. He has a big head and a wide chest and limbs which appear to be ridiculously out of proportion to his burly trunk. He begins to pursue every available form of exercise and outdoor recreation, and in a few years he has sprung up. His wide chest has stood him in good stead, and his limbs are now no longer out of keeping with his body.

The following account of the normal proportions of the body is founded upon that given by Mr. Roberts in his 'Manual of Anthropometry.'

The Head.—Of all parts of the body, the head varies least in its proportions during growth. In the average adult it is considered to form the seventh part of the whole height. From birth to the period of full development the head only doubles its height, while the whole body elongates three or four times its original dimensions. The most active growth of the head is during the first two years of life. The lower parts of the face grow at a greater rate than the upper, and all the horizontal measurements of the head develop less than those of height.

The Trunk.—The height of the neck increases irregularly. The most rapid growth is at puberty. The neck ultimately attains to double its original dimensions. The other parts of the body increase with greater energy, and growth is greater the further the parts are situated from the summit of the head. Thus, while the measurements of the head and neck are only doubled, those of the trunk are tripled, and those of the lower extremities are more than quadrupled. The transverse diameters of the trunk increase nearly in the same ratio as the height. They triple from birth to the period of full development. At the age of six or seven, this diameter is already doubled. The antero-posterior diameter of the thorax increases less rapidly and is not doubled until about puberty.

At the time of birth, when the child is about the sixth of the height it will ultimately attain to, the point which divides the total height into two equal parts is a little above the navel; at two years of age it is at the navel; at three years, when the child has attained half its total height, the central point is on a line with the upper borders of the iliac bones; at ten years of age, when the child has attained three-fourths of its total height, the central point is on a line with the trochanters; at thirteen years it is at the pubes, and in the adult man it is nearly half an inch lower. In the adult woman the central point is a little above the pubes.

The Upper Limbs.—The space covered by the arms extended horizontally is equal to the total height of the body, from birth to puberty.

In the adult man the ratio of the height to the measurement of the extended arms is as 1 to 1·045; and in the adult woman as 1 to 1·015. The length of the arm—excluding the hand—is doubled at the age between four and five years, tripled between thirteen and fourteen, and quadrupled at the period of full development. The hand develops less rapidly. Afterthe age of seven or eight the length of the hand has the ratio to the total height of one to nine. This applies to adults both male and female.

The Lower Limbs.—The lower extremities in adults are five times the length they were at birth. They double their length before the third year, and at twelve they are four times their original length. The length of the thigh varies considerably and has much to do with the differences in the total height of individuals. The foot at all ages of life and in both sexes forms from the 0·15 to 0·16 of the total height of the individual. It is only about the age of ten that the length of the foot is equal to the height of the head. Before that period the head is the longer, and after it the shorter.

The perfect Female Form.—The relative proportions of a perfect female form as deduced by modern sculptors from Greek statues have been given as follows. Her height will be five feet five inches. With the arms extended the measurement from finger-tip to finger-tip should be equal to her own height. The hand should be $\frac{1}{10}$th of this, the foot $\frac{1}{7}$th, and the chest diameter $\frac{1}{5}$th. From her perineum to the ground she should measure just what she measures from the perineum to the top of the head. The knee should be midway between the perineum and the heel.

The distance from the elbow to the middle finger should be the same as from the elbow to the middle of the chest. The head should be about the length of the foot. A woman of this height should measure 24 inches about the waist, 34 inches around the chest if measured under the arms, and 43 if measured over them. The upper arm should measure 13 inches and the wrist 6. The circumference of the thigh should be 25 inches, of the calf of the leg 14½ inches, and of the ankle 8 inches.

In determining the rate of growth and development of the body the following system of measurements, advised by Mr. Maclaren and given in his well-known work, may be followed out:—

System of Measurements

Height (without boots).—The position of attention, the heels together, the knees braced back, the chin raised, the head held steady, the shoulders square to the front, the heels, hips, shoulders, and head touching the pillar of the standard.

N.B.—This measurement, when repeated, should always be taken at the same time of the day, and after the same amount of bodily exertion.

Weight.—In working costume, i.e. in light shoes, flannel trousers, flannel shirt or jersey.

N.B.—This measurement when repeated should always be taken at the same time of the day, and with reference to any circumstance which would affect its accuracy.

Chest.—Over the jersey or naked breast. The position of attention, but with the arms horizontally extended, the palms of the hands held upwards and open, the finger straight. The tape should be passed around the chest in the line of the nipple.

N.B.—Care must be taken that the chest is not inflated beyond its usual expansion during ordinary breathing. Where a single measurement is taken the above line is the best, as gauging approximately at once the muscular and respiratory capacity; but when the latter quality is of primary importance (as in rowing) a second measurement should be taken lower down the chest, the tape being passed over the ninth rib.

In measuring recruits in the British army, the man stands erect, with the arms hanging loosely by the side. The lower edge of the tape should touch the nipple. The man is required to count ten slowly during the operation, to prevent him from keeping his lungs over-inflated.

Forearm (skin measurement).—The arm extended as in the preceding measurement, but with the hand tightly closed, the tape to be passed around the thickest part of the arm, and its girth at that point reckoned.

N.B.—With men who have taken little exercise this line will always be found near the elbow joint, but as the limb becomes developed, and the numerous muscles of the forearm acquire bulk and power from exercise, the greatest girth will be found from 2 to 3 inches below it. Unless this circumstance be kept in view the actual increase will not be perceived.

Upper arm (skin measurement).—The hand closed, the arm bent at the elbow, and the hand brought down towards the shoulder. This should be slowly and gradually done, bending the joints of the fingers, clenching the fist, and bringing the forearm down upon the upper arm, the tape to be passed in a straight line around the thickest part of the arm.

N.B.—When the whole arm is fully developed, the difference in size between the fore and upper arm in an adult of medium stature will be about 2 inches, and it will almost invariably be found that when the upper arm is feeble the upper region of the chest will be feeble also. With a chest of 40 inches the arm would probably be 12 inches and 14 inches.

Calf (skin measurement).—The limb to be held stiff and straight, the heel raised from the ground, the toes pressed strongly down, and the knee braced back. The tape is to be passed around the thickest part of the calf; and as the position of this line will somewhat vary with different men, and with the same limb in different stages of development, one or two points should be tried and that which shows the greatest girth selected.

Thigh (skin measurement).—The limb placed as in preceding measurement, the tape to be passed in a horizontal line around the thickest part of the limb, which will be at the highest point of the thigh admitting of horizontal measurement.

2. The Effect of Exercise upon the Muscular and Nervous Systems

Of the exact changes which take place in active muscle, and of the circumstances attending muscular contraction, it is needless to deal at any length. The matter is fully considered in every text-book of physiology.

The following brief account of the metabolism in muscle may be given. In an active muscle the blood-vessels are dilated. The neutral or feebly alkaline reaction of the passive structure becomes an acid reaction when the muscle is contracting, owing, it is supposed, to the formation of paralactic acid. A considerable quantity of carbon dioxide is excreted from the active muscle, while a large proportion of oxygen is consumed. The amount of glycogen and grape sugar is diminished in an active muscle, the tissue of which contains less extractives soluble in water, but more extractives soluble in alcohol. During exercise the amount of water in muscular tissue increases, while that of the blood is diminished in proportion. Heat is formed in a muscle in a state of activity.

Turning to more general matters concerning the muscular system, it has been well said that 'function makes structure,' and it is certain that muscular exercise makes muscular tissue. Not only is the exercised muscle increased in size, both as a whole and as far as its individual parts are concerned, but there is eliminated from it such tissue as is other than muscular. The fat contained among its meshes is reduced to a minimum, the connective tissue is lessened in amount, the aponeurotic parts are strengthened, and the structure of the muscle is so amended that it is hampered by no material other than that concerned in actual movement. It is freed, moreover, of such nitrogenous substances as are capable of giving rise to superabundant waste products of combustion.

There is a limit, of course, to the growth of muscles, and muscles exercised to too great an extent will, after attaining a certain size, commence to waste. The contractile force of the muscle is increased and an improvement takes place in those conditions which insure the speedy and complete contraction of its fibres. It has been pointed out that the muscles of an athlete when in training contract with extraordinary force under the electric current: the muscular sense is developed to its utmost, and the circumstances involved in the performance of a reflex act are placed under improved conditions; the power of co-ordination possessed by the individual is augmented; he acquires the art of causing muscles, which may be said to have been hitherto estranged, to act in concert, so that movements which were complex and effected with difficulty are ultimately carried out with ease. In this way the nervous system is saved a great expenditure of force. Acts which were performed with effort and by conscious will become automatic, and there is a saving in the expenditure of active force in the spinal cord and in the cerebral cortex. Complicated movements become 'organically registered in the brain' and cease to be difficult. One conspicuous feature in muscular training is the increase in the possibilities of automatism. As time goes on, and the individual practises more and more, he finds the work become easier and easier. This depends, not only upon an increase in the actual strength of the parts, but upon the greater ease with which the muscles concerned act in co-ordination and upon the muscular experience of the individual, which prevents him from misplacing his strength, and enables him to attain a desired end with the minimum amount of force.

He who is beginning to practise any muscular exercise, such as fencing,

bicycling, or rowing, will feel that he moves stiffly. The constant comment of the instructor in physical exercises is, 'Don't keep so stiff!' 'Let your arms go loose!' The beginner has not yet learnt how to balance one set of muscles against their antagonists. His movements are at first very deliberately planned, but in time the will ceases to concern itself. A memory is developed in the spinal cord and in the muscular centres, and one great element of fatigue is removed.

Nothing in physical training is more remarkable than the economy of force which results from muscular education. The well-trained athlete, moreover, acquires the art of using his respiratory muscles with the greatest economy. He does not exhaust himself with needlessly vigorous breathing; he learns to precisely regulate his respiratory movements to his immediate needs, and he brings the muscles of his thorax into co-ordination with the other muscles which he employs.

Just as muscles increase with use and waste with disuse, so the whole nerve apparatus concerned in movement is structurally improved by systematic exercise. The athletic man has better developed nerves, a more elaborate organisation of his spinal cord and of certain parts of his brain, than has the individual whose muscular system is imperfectly formed. Just as a certain segment of the spinal cord and of the cerebral cortex wastes after the removal of a limb, so it may be inferred that those parts become hypertrophied and elaborated when the limb in question is unusually employed.

'The differences,' writes Sir Crichton Browne, 'which we notice between man and man in deportment, gait, and expression are but the outward and visible signs of individual variations in the development of the motor centres of the brain; and the stammerings, grimacings, twitchings, and antics which are so common and annoying, alike to those who suffer and who witness them, are probably in many instances the effects of neglected education of some of those centres, and might have been abolished by timely drill and discipline.'

He who has been well trained physically possesses not only a complete but an intelligent use of his muscles. His movements are powerful, are under absolute control, are precise, and capable of the finest and most elaborate adjustment.

The art of the athlete consists, not in employing the greatest amount of power in effecting a movement, but in carrying out that movement with the least possible expenditure of force. The tyro at cycling will use an amount of muscular force in riding a mile which would probably carry an experienced rider some twenty miles.

3. The Effect of Exercise upon the Tissues and Organs generally

It is needless in this place to deal with the subject of bodily heat, with the manner in which it is developed and employed, with the conditions which regulate it and attend its disposal. It is necessary only to say that in the body work and heat are always associated, and it is believed that the heat is the cause, and not the effect, of the work. No muscular contraction can occur without the production of heat, but of the precise manner in which heat acts upon muscle and makes it contract little is known.

Commenting upon this matter Dr. Lagrange, in his work on 'The Physiology of Bodily Exercise' (page 37), observes: 'Heat causes in muscular fibres the first stage of contraction, or at least an aptitude for coming into action more quickly under the influence of the will. A heated muscle seems to have stored, in a sense, a latent force. It has been ascer-

tained that the maximum aptitude for contraction is exhibited by human muscles at about 40° C. It follows that a man whose muscles are at this temperature is able to act more quickly, and at once can make use of all his force.

'A bodily exercise is performed with more vigour and ease when heat has raised the temperature of the muscles. This fact is so well known that there are characteristic phrases to express it in common speech. We say of a man beginning an exercise of strength or skill whose movements have not yet acquired all their force and precision, that he has not yet warmed to his work.'

The author compares the preliminary canter before a race, the preliminary sparring before a fight, and the strange movements of an angry animal before an attack, to the heating up of a locomotive. It may be pointed out, also, that there is a greater aptitude for bodily exercises in summer than in winter, and that muscular action becomes temporarily paralysed by great cold.

The heat produced in the body depends upon certain chemical changes in the tisssues, certain combustions which are mostly, but not exclusively, oxidations. These products of combustion, or of dissimilation, examples of which are afforded by carbon dioxide, urea, uric acid, &c., are noxious to life and must be ejected from the body in one way or another through the agency of special organs. The effects produced by an excess or by a retention of these products are dealt with in discussing the subject of fatigue.

Muscular exercise tends, moreover, to remove any accumulation of fat which may exist in the tissues. Fat is the type of what are known as the reserve tissues. It serves the part of fuel for combustion; it undergoes dissimilation with remarkable ease, and may therefore be regarded as fuel of a most combustible character. As fat forms no permanent structural part of the organism, its removal is, within limits, effected with no inconvenience. The fat man who takes exercise finds that he soon becomes breathless and fatigued. His unwonted muscular exertion involves a great series of combustion processes. Fat would appear to be of all substances the one which most readily lends itself as material for such changes. The result is that in the corpulent individual the products of dissimilation are produced in excess, and he becomes, in a certain sense, poisoned by the accumulation of these products (see chapter on FATIGUE). He is hampered also by the unnecessary weight of his body, by his feeble muscles, and possibly, to some extent, by the mechanical obstacles offered by collections of fat. A corpulent man in rowing finds that his large abdomen is an actual mechanical obstacle in the way of his movements.

A fat man when in training loses his fat. As he becomes thinner he becomes stronger, his muscles act better, he is less breathless on exertion, less fatigued after long-continued effort, and may in time reach that excellent state of health known as 'good condition.'

The fat disappears first from the limbs, especially from the limbs which are particularly employed. Last of all the internal accumulations disappear, and the last feature to go will probably be the large abdomen, which is so terrible a trial to would-be athletes of middle age.

It may here be said that the deposit of a certain amount of fat within the abdomen is a common accompaniment of advancing age, and that its formation can best be prevented by exercise, and especially by such exercises as involve the contraction of the abdominal muscles. It is exceedingly rare to see a waterman who keeps up a good style of rowing present an unduly prominent abdomen.

Exercise, moreover, tends to improve the condition of the tissues generally.

The soft parts become firmer, more resistant, less easily bruised when damaged, and in all respects sounder. A man in training is said to be 'hard,' and it is well known that no moderate blow will raise a bruise upon the person of a prize fighter when he is in perfect 'condition.' The general standard of the nutritive activity of the body is improved. The stout and flabby man becomes thinner, harder, and firmer under training.

The thin and spare man, on the other hand, often becomes stouter under training. He feels better, eats better, and his powers of nutrition are so improved that he gains flesh and weight.

Thus training may cause one man to lose weight and another to gain it, and both to look healthier and better for the change.

As Dr. Lagrange well expresses it, 'Exercise produces in the system two absolutely different effects: it increases the process of assimilation, thanks to which the body gains new tissues, and it accelerates the process of dissimilation, which leads to the destruction of certain materials.' Its action in the former direction depends upon the increased amount of oxygen introduced into the system by the improved circulation and respiration and by the healthy stimulation of the various active organs of the body.

The need for exercise is felt as much by thin people, who assimilate too little, as by fat people, who do not dissimilate enough. Exercise may therefore be regarded as a great regulator of nutrition.

As the action of the heart rapidly increases in force and frequency during exercise, the flow of blood through all parts of the body is increased. The amount of increase is from ten to thirty beats, but it may be more. The skin becomes red with the blood contained in the full capillaries and perspiration is much increased. The amount of fluid which is lost by the skin is very considerable.

The digestive apparatus is stimulated and strengthened by exercise. The appetite improves, digestion is more complete, absorption more rapid, and the circulation through the liver is more vigorous and even.

Muscular exercises, especially such as employ the muscles of the abdomen, have a very beneficial effect upon the bowels, promoting peristaltic movements and relieving such constipation as depends upon the torpidity of the intestine.

One other conspicuous effect of exercise is the increased elimination of carbon. This is eliminated mainly by the lungs. The observations of Pettenkofer and Voit give the following results:—

TABLE IX.

—	Absorption of oxygen in grammes	Elimination in grammes of		
		Carbonic acid	Water	Urea
Rest day	708·9	911·5	828·0	37·2
Work day	954·5	1284·2	2042·1	37·0
Excess on work day (with exception of urea)	246·6	372·7	1214·1	−0·2

It is demonstrated that a considerable formation of carbonic acid takes place in the muscles. As, moreover, exercise is clearly necessary for a sufficient elimination of carbon from the body, it is needful in a condition of prolonged rest that the amount of carbon in the food be lessened to avoid an accumulation of that element in the tissues.

With regard to the vexed question of the elimination of nitrogen from the body during exercise, Parkes concludes his careful examination of the subject in these words :—

'On the whole, if I have stated the facts correctly, the effect of exercise is certainly to influence the elimination of nitrogen by the kidneys, but within various limits, and the time of increase is in the period of rest succeeding the exercise; while during the exercise period the evidence, though not certain, points rather to a lessening of the elimination of nitrogen.

'It would appear from these facts that well-fed persons taking exercise would require a little more nitrogen in the food, and it is certain, as a matter of experience, that persons undergoing laborious work do take more nitrogenous food. This is the case also with animals.'

Dr. Parkes thus sums up the action of exercise upon the kidneys : 'The water of the urine and the chloride of sodium often lessen in consequence of the increased passage from the skin. The urea is not much changed. The uric acid increases after great exertion, so also apparently the pigment ; the phosphoric acid is not augmented ; the sulphuric acid is moderately increased ; the free carbonic acid of the urine is increased ; the chlorides are lessened on account of the outflow by the skin ; the exact amount of the bases has not been determined, but a greater excess of soda and potash is eliminated than of lime or magnesia. Nothing certain is known as to hippuric acid, sugar, or other substances.'

4. The Effect of Exercise upon Personal Comeliness and Comfort

We have already noted the effect a systematic training may have upon the growth and development of the body, upon the size of the chest, and the proportions of the limbs. Such training, moreover, can give an upright and symmetrical figure and an easy and graceful carriage. There is a swing about the body and a bearing of the head and shoulders which mark those whose muscular system has been fully developed.

Under proper training the shuffling and shambling gait disappears, the loutish boy ceases to look loutish, and the gawky girl no longer excites comment ; rounded shoulders become square and bending backs are made straight.

The athlete, so far as his body and his personal equation are concerned, has reached the full and perfect stature of a man, and the girl whose physical education has been complete reaches her point of physical perfection as a woman. The beauty of the body depends upon a fully formed skeleton and perfectly developed muscles, and not upon deposits of fat. The arm of a plump but ill-developed woman is rounded and free from conspicuous prominences about the elbow, but the outline is as meaningless and as unnatural as the part is flabby and lifeless. The arm of a woman in perfect physical condition has, on the other hand, an exquisite outline. It presents the contour given it by the muscles that move the limb. The graceful configuration of these muscles has not been hidden beneath a monotonous layer of fat. The arm has an individuality and has reached the perfection of its growth. The beauty of the right arm of many female violinists is a matter of common comment.

Unfortunately there is comparatively little fat about joints, and the most trying feature in the feebly developed woman is a bony elbow. There are masses of muscle about the elbow, and if these are wasted the details of the skeleton become unpleasantly conspicuous. If they are, on the contrary, well developed, the contour of the elbow becomes even and graceful. The arm of an individual who is not only thin but is also ill-developed is an unpleasant spectacle—it is a burlesque of a human limb.

In the neck and the upper part of the chest the effects of a sound physical training are very conspicuous. The long turkey-like neck of the ill-developed lad and the scraggy neck of the ill-nurtured woman are familiar enough. They are both unnecessary disfigurements.

A perfectly shaped thorax gives to the human figure its most striking feature, and such a chest cannot be met with among those whose physical education has been quite neglected. There is little excuse for an ill-formed thorax, and yet at the present day it is met with on all sides and in all classes of the community.

The back of the ill-developed is characteristic. The spinous processes of the vertebræ, instead of being sunk in a median groove formed by the two great masses of the vertebral muscles, stand out in the form of an irregular nodulated ridge. The back looks feeble, lifeless, wasted, and there is an air of muscular pauperism about it. It looks poor, and yet it must be owned that it is the type of back very commonly met with among the favoured classes, and especially among the women.

The tissues of the ill-developed are flabby, doughy, baggy. They lack elasticity and consistence. The cheek of the overworked shop assistant who gets no real exercise can be seen to shake as he walks along the street.

The purposeless-looking extremities of those who are physically uneducated are well known. They have the appearance of the limbs of individuals who are recovering from serious illness. They are, as a matter of fact, the extremities of persons who have never been well.

The tissues of the well-developed are firm, elastic, resisting, active, and full of evidence of living. There is given to every part of the surface of the body that rapid change in contour and that indescribable aspect of vigour and soundness which are features of a healthy and well-knit frame.

In the above comments I am alluding merely to the results of a systematic physical training, and not to such exceptional results of muscular exercise as produce professional gymnasts and acrobats.

Undue and unsymmetrical muscular development may deform the body; a circumstance well illustrated by some acrobats, whose lower limbs are of normal or sub-normal development, while their arms are enormous, their shoulders mountainous and uncouth, their necks coarse and bullock-like, and the upper part of the back arched or bowed. This is especially noticeable in gymnasts who practise upon the trapeze, horizontal bar, and other apparatus, and who have exclusively developed the muscles of the upper half of the trunk.

The skin of those who have taken pains to bring their bodies to perfection often compares in a marked manner with the integument of the neglected and uneducated. It is firm, clear, and wholesome. It is not to be argued that exercise will keep the integument free from marks and blotches, and render a naturally coarse skin fine, but it will bring about such differences in appearance as serve to distinguish what is healthy from what is unsound. The delicate and sensitive complexion of a young woman whose physical training has been efficient is in conspicuous contrast with the dull, loose, lustreless integument of the abstainer from muscular pursuits. The skin of the recluse is grey, greasy, and unpleasant-looking. The complexion of the young man about town is almost distinctive. It is aggressively unwholesome, and forms a contrast with that of his companion who has just returned from a shooting expedition or a long boating tour. Exercise, of course, involves more living in the open, a freer and deeper respiration, and the coursing of a more vigorous flow of blood through the integuments; it leads actually to a sounder state of the general health, and such improvement is at once evident upon the skin. There is a certain brightness and vivacity of the look, and a

certain degree of self-assertion in the carriage, of those who are in sound physical condition. They contrast with the wan, hopeless-looking creatures who never 'stir out of the house,' and who crawl through life in a semi-apologetic manner.

In the matter of personal comfort no greater sense of pure pleasure can influence the human mind than that which results from perfect health. There is the glorious delight of movement and of vigorous activity, quite apart from the excitement and mental enjoyment which attend so many recreations and outdoor sports. The lad who is in perfect physical condition wakes up in the morning, fresh and rampant; and if it be the summer time he probably feels an irresistible impulse to dash out into the open air and fill his lungs and quicken his pulse and move his muscles. Even the fatigue that comes over a man who is in good condition, and who has taken a long spell at exercise, is pleasurable. Such a one eats well and digests well; the functions of his body are carried on normally, and he experiences to its full the delight of living.

The youth who takes no exercise, who is always poring over his books, misses at least one-half of the enjoyments which are available to man during a comparatively short life. He is a dull creature, dyspeptic probably, the subject of headaches, constipation, and many minor ills. To him joy cometh not in the morning, and in the place of an honest fatigue he has the 'fidgets' and his weariness is painful. His appetite is feeble possibly, his circulation is poor, and very often he sleeps badly, and can envy the easy and profound sleep of a companion who has come home after a long run across country. The simplest, the purest, and the pleasantest recollections in life usually go back to certain physical enjoyments in the open air, to some walking tour or cricket match, to some river expedition, or to some great day upon the moors.

When sudden exercise is forced upon the undeveloped individual, he is more or less unable to meet it; he becomes breathless, perspires violently, is uncertain of himself, is clumsy and the subsequent victim of a painful degree of fatigue. Of such a person it cannot be said—

> Yea, this in him was the peculiar grace,
> That before living he learned how to live.

5. The Mental and Moral Effects of Exercise

Moderate, regular, and systematic exercise by stimulating the circulation of the body improves also the circulation of the brain, and is therefore an aid to cerebral movements. It improves the health and the physical strength, and so increases the capability of the individual for mental work and for the physical strain incident upon mental concentration.

By organising in the brain a series of muscular movements, by elaborating the powers of co-ordination, and by establishing automatism in a large and varied series of actions, it saves actual brain-work and renders a considerable number of movements independent of the direct action of the will.

It offers, too, an admirable change of employment. There is no better rest from severe mental work than well-selected bodily exercise. With many men to lie upon a beach and throw stones into the water is no rest. They would find a more complete repose in the pleasurable use of their muscles, in the pursuit of some congenial outdoor sport, and in rendering dormant the energies of one part of the nervous system by an engrossing employment of another part.

Such exercises as are indulged in when seeking rest from mental work must be simple and, so far as possible, such as are automatically performed.

'Prescribe fencing, gymnastics with apparatus, and lessons in a riding school,' writes Dr. Lagrange, 'to all those idle persons whose brain languishes for want of work. The effort of will and the work of co-ordination which these exercises demand will give a salutary stimulus to the torpid cerebral cells. But for a child overworked at school, for a person whose nerve-centres are congested owing to persistent mental effort in preparing for an examination, for such we must prescribe long walks, the easily learnt exercise of rowing, and, failing better, the old game of leap frog and prisoner's base, running games—anything, in fact, rather than difficult exercises and acrobatic gymnastics.'

'Mr. Charles Paget, at one time M.P. for Nottingham, tried in the village school on his estate at Ruddington a very interesting experiment. He was not satisfied with the general progress made by the boys, and he provided for them a large garden. The school was then divided into two sections, one of which was kept to the ordinary school work for the ordinary hours, the other for half of these hours only, the rest of the school-time being devoted to work in the garden. At the end of the term the half-time, or gardening boys, had excelled the others in every respect—in conduct, in diligence, and in the results of study' ('Health Exhibition Manuals,' vol. xi. p. 327).

There must be a proper distribution of mental and physical work. Just as 'all work and no play makes Jack a dull boy,' so all play and no work makes Jack a still duller boy.

An excessive and absorbing indulgence in physical exercises is undoubtedly bad. It tends to make the individual too much of an animal and to afford neither time, opportunity, nor suitable conditions for the development of his brain. Under such circumstances even the body tends to become stunted if the practice be commenced early, and the lad develops not only an animal look, but some of the intellectual and emotional attributes of the animal.

Still, on the other hand, in these days of cramming and intense competition, many a successful man has to thank Providence for the late recognised blessings of an idle youth.

The systematic and properly arranged pursuit of physical exercise tends to develop certain admirable qualities, and notably those which are so much prized among Englishmen, and which are well designated as 'manly.'

These qualities are brought out in those who are enthusiasts in outdoor sports and games. The football player has done more than merely develop his muscles; the man who has rowed in his college eight has learnt something beyond the mysteries of the sliding seat; and the experienced 'player' at almost any outdoor game has been improved by other means than those which the actual manœuvres of the game demand. Such lads and men have learnt in a school where the principles of pluck, courage, endurance, and self-reliance are acquired. They have probably learnt to be ready, to be quick of eye and hand, and prompt in judgment. They may have appreciated the value of discipline and of self-control. They may have felt the inspiration of the chivalry of days gone by, and have experienced the influences of good fellowship and loyal comradeship. They may have learnt what it is to be patient, to be fair, to be unselfish, and to be true.

Many a man who in later life finds himself in a dangerous strait would wish for no one better by his side than the lad who pulled behind him in a racing eight. The cries and the cheers of the football field must have

given heart to many a desperate soldier when hard pressed in the turmoil of actual war, and a sailor can say no more gracious thing of his mate than that he is 'a man to stand by you in a gale.'

There is a certain moral effect also which comes with a sound physical training. The schoolboy who is foremost in athletic exercises will probably be found to be more open, more straightforward, more simple, and more wholesome-minded than the lad who spends his time loafing at the pastry-cook's. Mr. Cathcart in his 'Health Lectures' (Edinburgh, 1884) brings this point well forward in the evidence he quotes from certain head-masters of large public schools in England. One head-master writes: 'The worst boys intellectually, physically, and morally are the loafers,' and another: 'The boys who work hard and play hard do not ape the vices of men, and are free from the insidious evils that often fasten on unoccupied boyhood.'

I think it may be safely said that that miserable creature, the juvenile sexual hypochondriac, is never to be found among those who are foremost at athletics and outdoor games.

FATIGUE

This subject will be considered under the following heads: 1. Breathlessness; 2. Muscular Fatigue; 3. Muscular Stiffness; 4. General Fatigue.

1. Breathlessness

The breathlessness which is a familiar attendant upon exercises of a certain character has received but little notice at the hands of physiologists. Dr. Lagrange has in his recent work, to which allusion has been already made, dealt very fully with the subject, and explains it by a theory which appears to be both sound and satisfactory. The phenomena of breathlessness are familiar enough. One has but to picture a man of middle age, who is out of training, and who has set himself the task of running a certain distance. He soon feels embarrassed in his breathing; he pants, his respiratory movements become jerky and irregular; he is aware of a terrible sense of oppression in his chest, a sense which increases with each step. His head throbs; he begins to find that his strength is failing him; he feels that he could run many more yards, so far as his legs are concerned, but the sense of suffocation arrests him. He staggers along, his steps become uncertain, his face haggard, his movements irregular, and he stops at last dead beat. As he rests he continues for many minutes to breathe in the same troubled way. The man is said to be 'blown,' to have 'lost his wind.' He has used his legs, but his legs have not given way. It is his chest which has failed him. This constitutes the remarkable feature of the phenomenon. The same man can exercise his arms with dumb-bells for three times the time occupied by the run, yet he is not 'out of breath.' He can row for ten miles without being inconvenienced, but he cannot run up two flights of steep stairs without being rendered quite breathless. The more athletic the man, the better condition of training he is in, the more practice he has had, the less breathless he becomes; but the most perfect athlete, even when in his prime, can soon 'pump himself out' if he tries.

Dr. Lagrange offers the following explanation of the phenomenon:—

Breathlessness is a form of dyspnœa due to an excess of carbon dioxide in the blood. The excess of this gas leads to an increase of the respiratory need. The condition may be spoken of as auto-intoxication of the body by one of its own products of dissimilation—carbon dioxide.

This excess of carbonic acid is produced by muscular work. It is a conspicuous product of such work, and it must be remembered that the muscles form at least half the weight of the entire body. The larger the muscles employed, and the more vigorous their action, the greater is the amount of the gas produced. The intensity of breathlessness during exercise is in direct proportion to the expenditure of force demanded in a given time. Running involves rapid contractions of the great mass of muscles forming the lower extremities. It induces breathlessness quicker than does moderate rowing, where the muscular expenditure in a given time is much less. 'The quantity of carbonic acid,' writes Dr. Lagrange, 'produced by a group of muscles in a given time is in proportion to the amount of work they do. Further, the work which a group of muscles is able to do without fatigue is in direct ratio to the power, that is, to the number and size of the muscles forming this group. If, then, an exercise is localised in a very small group of muscles, fatigue will ensue before a large quantity of work has been done, and before a large dose of carbonic acid has been poured into the blood. The eliminating power of the lungs will exceed the power for work of the active muscles; muscular fatigue will precede breathlessness. If, on the other hand, the muscles put in action are very numerous and very powerful, they will be able before being fatigued to perform a large quantity of work, and consequently to produce a very large dose of carbonic acid. Their power for work will exceed the eliminating power of the lungs. Breathlessness will this time precede fatigue.'

It is said that a horse 'trots with its legs and gallops with its lungs.' The gallop of a horse may be slowed down until the animal falls behind another horse which is trotting. Nevertheless, however slow the gallop may be, it will more quickly 'pump' a horse than an equally rapid trot. Swiftness of movement does not suffice to produce breathlessness unless combined with intensity of muscular effort.

In breathlessness it is not inspiration which is difficult, but expiration. In running, inspiration is free, easy, deep, three times as long as expiration. The latter, on the other hand, is short, insufficient, and painful.

It is stated that in man there is discharged in a given time by respiration

0·35	gramme	of carbonic acid	during	sleep.
0·60	,,	,,	,,	while sitting.
1·65	,,	,,	,,	while running.

As accessory causes of breathlessness are certain disturbances in the circulation of the blood and some engorgement of the lungs resulting therefrom. These changes are discussed by Dr. Lagrange in the following words:—

'The first result of violent exercise is the quickening of the blood current and a consequent active congestion of the lungs. In these exercises the lungs are very quickly engorged with blood, and there is great need for their disembarrassment by increasing the activity of the blood current. The movement of inspiration increases the velocity of the current by a force of aspiration which tends to empty the over-filled capillaries. This aspiration lasts as long as the enlargement of the thorax continues; hence this movement is an assistance to the breathless man; on the other hand, as the thorax is diminishing in size during the expiratory movement, the blood current becomes slower and the lungs more engorged. Hence the discomfort and the irresistible impulse to a prompt repetition of the inspiratory movement.

'We may say that the lungs of the breathless man are placed between two different needs. On the one hand, they have to drive out carbonic acid and

the other products of dissimilation, and for this a long expiration would be necessary; but, on the other hand, they have to free themselves from vascular engorgement, and therefore expiration is cut short to return to inspiration, which helps the circulation through the lungs.'

Dr. Lagrange divides breathlessness into three stages, and, as he is the only writer who has fully dealt with this subject, the matter cannot be better discussed than in his own words:—

'In the *first stage* the respiratory movements are increased in frequency and in extent. The production of carbonic acid is increased, but, the respiratory energy being greater, there is an equilibrium between the needs of the organism, which demands a more active elimination of this gas, and the working of the lungs, which is powerful enough to satisfy these needs. During a time which varies much with the individual, with his constitution, with his resistance to fatigue, and, above all, with his power of directing his respiration, gained from his respiratory education, these are only symptoms of greater vital activity, and there are as yet no signs of functional disturbance, no sensation which rises to the degree of discomfort. The man has a general sensation of warmth, some throbbing of the temples, and has an animated appearance, flushed, his eyes sparkling, and a general aspect of cheerfulness, due to the greater activity of the circulation and the resulting active congestions. In a word, it is the stage in which exercise causes a greater intensity of life without reaching the degree of discomfort or of danger.

'Here we have the really salutary dose of exercise, the limits within which we must keep in order that work may cause us no inconvenience. But nothing varies more with the individual than the duration of this inoffensive period, which is, in a sense, the preface of breathlessness. In some persons it is as long as an hour, in others the stage in which discomfort begins is reached in a few seconds.

'If violent exercise be prolonged, the equilibrium is soon broken between the production of carbonic acid, which becomes more and more abundant, and the eliminating power of the lungs, which is insufficient to free the organism from it. Respiratory distress occurs.

'In the *second period* the effects of insufficient respiration begin to show themselves, a vague discomfort is experienced, which is most accentuated in the præcordial region, but which is rapidly generalised throughout the body, and notably affects the head. In the chest there is a feeling as if it were oppressed by a weight, or bound down by a girdle of insufficient air. In the head there are clouds obscuring sight, sparks before the eyes, then murmurs and ringing in the ears, and finally a certain bluntness of sensation, a certain confusion in impressions and in ideas. All these disturbances are due to the action upon the nerve-centres of an excess of carbonic acid. They indicate the beginning of intoxication.

'In the face, remarkable changes are to be noticed, which are the consequences of the respiratory distress, and of the efforts made to draw a greater quantity of air into the chest. The nostrils are dilated, the mouth and eyes widely opened. They all seem to be widely opened to favour the entrance of the air which the lungs so greatly need.

'The colour of a breathless man shows very striking modifications. At the beginning of exercise we have said that there is animation, more colour in the face, due to active congestion. But in the second period the picture has changed. To the lively red colour has succeeded a pale and wan tint. There is something peculiar about this pallor—it is not uniform. Certain parts of the face, such as the lips and the cheeks, have a violet blackish appearance; the rest of the face is white and colourless.

'From the two colours, one darker and the other lighter, there results a grey, leaden, livid appearance. The violet tint is due to the retention of blood in the capillaries, which are losing their elasticity, and in which the circulation is failing. This blood, overcharged with carbonic acid, has lost its bright red colour, hence in the lips and other more transparent parts of the face we see no longer the ordinary red colour; they have the blackish colour characteristic of venous blood.

'As for the pallor, this is due to a transient anæmia, to the emptying of the arterioles. The heart, the energy of which diminishes in proportion to the increase of the breathlessness, does not send forward a sufficient quantity of blood, and it is easy to understand that a part receiving less blood is less deeply coloured than usual.

'The leaden hue of the face in a breathless man indicates an already profound disturbance of the system. In no case should exercise be continued after it comes on, for it indicates the beginning of asphyxia.

'It is at this stage of breathlessness that we observe the very characteristic change in the rhythm of respiration which has been already described. The ordinary rhythm is lost, and the two periods of respiration become unequal. The first period increases and the second diminishes; inspiration becomes three times as long as expiration. This change in the rhythm of respiration is an indication of blood stasis in the capillaries of the lungs. As soon as it occurs we can see that the organism, its force exhausted, can no longer fight to good purpose against the poisonous substance which permeates it. The congested lungs eliminate less carbonic acid than is formed by the muscles at work. Intoxication is imminent.

'If exercise be continued, the gravity of the condition rapidly increases. We may call the asphyxial stage the third phase of breathlessness into which the organism passes under the influence of forced exercise.

'This *third stage* is as follows. To the respiratory distress succeeds a sensation of anguish generalised throughout the organism. The head feels as if bound by an iron band. Vertigo is very distressing. All sensations become more vague; the brain is overcome by a kind of drunkenness. The subject begins to become unconscious of what is passing, his muscles continue to work mechanically for a time, then they stop, and the man falls in a faint.

'At this time respiration is of a different type to that of the last stage; the two periods are both short, jerky, occasionally interrupted; with them are mingled swallowing movements and hiccough. The heart-beat is feeble and intermittent. The pulse is small, irregular, and imperceptible. When exercise is continued to these extreme limits it is almost always stopped by grave syncope, and unless prompt help be given the syncope may be fatal.'

An athletic man soon develops the art of regulating his breathing so as to reduce the degree of breathlessness as far as is possible. He is aware that it is at first that the trouble is intense, and that in time he can adjust the difficulty a little. The runner speaks of getting 'his second wind.' He has passed through a period of breathlessness in which excitement, sudden movement, and unnecessarily extreme muscular contractions possibly have played some part; he then settles down to his work, he uses his forces more economically and breathes more easily; and it is common to hear a man out of condition explain the loss of a race by the fact that he never got his 'second wind.'

In sprint running the art of controlling breathlessness reaches its highest point, and to some extent sprint running is a test of the respiratory capacity in this direction.

2. Muscular Fatigue

If a man in sound health hold out his arm at right angles to his body he experiences, in a time which varies according to his physical condition, so much inconvenience in the muscles involved that he is at last compelled to drop the limb. If he exercise his will to the utmost he may prolong the period of extension, but a time soon comes when by no possible effort can he continue to hold out the extremity.

The muscles in question are said to be fatigued.

The fatigue is termed relative because, if a proper electric current be applied to the muscles as soon as the limb is dropped as helpless, the muscles again contract, and the hand is once more lifted.

If the muscles of an animal be subjected to an electric current they contract; on repeating the application they contract again and again. The contractions, however, become feebler, and are in time ultimately abolished. The parts are in the condition of relative fatigue.

If now a stronger current be employed, the muscles again contract, and again in time lose their power. The experiment can be continued with a stronger current until finally the muscles cannot be made to contract by any current or any stimulus of any kind.

They have reached the state of absolute fatigue.

Local fatigue of muscle is explained by the following conditions:—

1. The actual power or function of the muscle is exhausted. This condition has been termed 'dynamic exhaustion,' and is parallel to the exhaustion which is noticed in certain reflex acts when they are indefinitely excited, and to the exhaustion of the retina to certain rays when one colour is contemplated for too long a time.

The functional power of a muscle is placed within definite limits, and in fatigue that limit is reached. This exhaustion is modified by the strength of the muscle, by its local condition, by the practice it has been subjected to, and by the nerve condition of the individual.

2. In fatigue, nerve exhaustion is largely concerned. This especially applies to complicated acts, the repetition of which involves a special and definite effort of the will.

The comparative absence of exhaustion in the incessant movements in chorea is explained by the circumstance that in these movements a voluntary nerve mechanism is not concerned. Dr. Lagrange lays down the axiom that, 'the muscular work being equal, the sensation of fatigue is the more intense the more active the intervention of the cerebral faculties demanded by the exercise.'

3. Some local effect may be exercised upon the muscle by the products of combustion or dissimilation which are developed within its tissues, and which, not being got rid of in time enough, accumulate in excess.

'If,' writes Dr. Lagrange, 'we submit the muscles of a frog to the action of a powerful electric stimulus, and prolong this action until fatigue is complete, that is, till the limbs of the animal remain motionless under the most powerful stimulation, we shall have in the fatigued muscles the elements necessary for a most curious experiment. Their substance rubbed in a mortar and made into a fine soup contains a principle capable of producing in healthy muscle at rest the fatigue which had exhausted the first muscles. If we inject into a second frog this extract of fatigued muscles, we bring about in this animal all the phenomena of fatigue, and its limbs will fail to respond to electric stimuli.'

The possible character of this local effect is thus dealt with by Landois in his well-known 'Text-book of Physiology' (translated by Stirling). The cause of local muscular fatigue 'is probably partly due to the accumulation of decomposition products—"fatigue stuffs"—in the muscular tissue, these products being formed within the muscle itself during its activity. They are phosphoric acid, either free or in the form of acid phosphates, acid potassium phosphate, glycerin-phosphoric acid (?), and carbonic acid. If these substances be removed from a muscle by passing through its blood-vessels an indifference solution of common salt . . . the muscle again becomes capable of energising.'

Dr. Lagrange gives a more detailed account of these tissue changes, and in adding his account it is necessary to say that his statements are not entirely in accord with the teaching of most physiologists.

'Muscles which have worked to excess have undergone a change in their chemical composition. Alkaline in a state of repose, they have become acid; they contain lactic acid, which was not present before work; they contain less oxygen and more carbonic acid than when at rest. Numerous nitrogenous materials resulting from the combustion of muscular tissues are considerably increased. These substances, of which the last stage of combustion is urea, form a series of bodies only differing in containing more or less oxygen, and being consequently at a different degree of oxidation or combustion. All authors enumerate amongst them kreatin, hypoxanthin, inosite, &c., and finally the best known one, and the most interesting because of the part it plays in the production of gout, uric acid.'

4. It is possible also that some actual lesion, such as that attending the compression of nerves, may occur in a fatigued muscle and may serve to partly explain the tenderness of the overused structure and to establish a condition akin to that produced by the violent and irregular contractions of cramp.

3. Muscular Stiffness

Another feature associated with local fatigue, with the overuse of muscle, is stiffness. This is a common but not a necessary accompaniment of the over-work.

A rowing man who is entirely out of condition, and who has taken no exercise for months, is asked to fill up a place in a racing four for a short 'practice.' He finds the exertion a terrible strain; he soon becomes breathless, his limbs ache, his head throbs, every limb seems out of condition, and he is soon exhausted. He does his best through the short spin, but next day he aches all over. He is stiff. He feels as if he had been beaten. He cannot move without some pain, nor can he grasp any part of his body without discovering some tenderness.

In a day or so the unpleasant condition passes off. This very man may have rowed many races without experiencing a trace of stiffness. He may have gone through three times the amount of exertion without any but momentary inconvenience. The difference has been simply this. At one time he was in practice and in condition, at the other time he was both out of practice and out of condition.

The intensity of the stiffness is not always proportionate to the immediate fatigue, nor is the extent of the exercise a measure of the stiffness which may result.

Stiffness depends rather upon the condition of the individual than upon the character or amount of the muscular work done. Muscles may be fatigued without afterwards becoming stiff.

The local symptoms of stiffness probably depend upon an exaggeration of those conditions in the muscles which are supposed to underlie local fatigue, and notably to the retention in the tissues of the products of combustion.

These local changes have already been described.

4. General Fatigue

The general disturbances which may accompany muscular exhaustion and which are present in some degree in such fatigue as is attended by stiffness are of very varying character.

The individual may be left simply exhausted, 'tired out,' listless, and to some extent prostrate.

In more advanced degrees he complains of heaviness in the head, of utter feebleness, of inability to take food, and of painful weariness and restlessness followed by want of sleep.

In other and still more pronounced cases he may exhibit febrile phenomena and present the condition described as the 'fever of over-exertion.' This fever may be attended with such malaise and with such nerve disturbances as to be mistaken for the early period of an infective fever.

This condition has been elaborately considered by Dr. Knott, of Dublin, in his excellent monograph on 'The Fever of Over-exertion' (Dublin, 1888). He takes the case of a greatly overworked farm labourer. The symptoms may or may not commence with a rigor. The patient's temperature runs up rapidly, even to 103° F. or 104° F. within a few hours, and this change is accompanied by the general symptoms of malaise, congested face, thirst, loss of appetite, &c. He sometimes takes a day or two of rest, when, feeling a little better, he makes a desperate effort to go back to work, although still suffering from the same symptoms in a slighter degree. His efforts are now necessarily less vigorous, but he does enough to feed the slow fire of febrile combustion which has been already kindled in his muscles.

The temperature maintains a standard of about 101° or so; the pulse is permanently quickened; thirst, constipation, loss of appetite, and loaded urine continue.

In such cases, when the pernicious attempts at manual exertion are continued for a number of days, the unhappy individual afterwards fails to recover. Gradual wasting goes on; the pulse maintains its frequency and becomes weaker, the strength by degrees fails, the patient is obliged to take to bed, the fever tends, after some months, to assume a hectic type. Increasing emaciation is marked, and the patient not very rarely falls a victim to some intercurrent disease.

Dr. Knott ascribes the phenomena to the throwing into the circulation of a greatly disproportionate quantity of the products of muscular waste. These, he maintains, lead to an overthrow of the governing powers of the thermotoxic nerve centre, or, in other words, are the substantial cause of the fever. He considers that urea and uric acid represent the most important of these products.

Dr. Lagrange supports the same view, and contends that the marked constitutional disturbances which may follow upon severe muscular exercise are all due to the accumulation in the circulation of a large excess of the chemical products of muscular waste, to a species of self-infection by the excess of combustion products developed in the muscles. He also considers that these products are mainly represented by urea and allied compounds.

It is noteworthy that a degree of fatigue leading to muscular stiffness, but not necessarily to the constitutional symptoms named, will be attended

by a deposit of urates in the urine. This may be quite independent of any fever.

Those who pursue athletic exercises are well aware of the association of a deposit in the urine with the appearance of stiffness. In a man out of condition the tissue waste induced during unwonted exercise is very considerable. The tissues afford abundant reserve material for the necessary combustions. The nutritive condition of his muscles is comparatively low. In an athlete in training, on the other hand, the material available for combustion is not in excess. The tissues have long been rid of all superfluous matter. The nutritive state of the muscles is in the best possible condition, and the circumstances which favour the development of a great deposit of urates is not forthcoming.

EFFECTS OF EXCESSIVE OR UNSUITABLE EXERCISE

It is unnecessary to deal in a separate section with the ill-effects of an absence of physical exercise upon the body. The matter has been considered in such of the foregoing paragraphs as are concerned in the general effect of muscular exercises.

In estimating the actual value of the work done in any physical pursuit, or in attempting to express what is meant by 'excessive' or 'unsuitable' in relation with muscular labour, I have been unable to make any use of the physiological method of measuring work by 'foot-tons.' This mode of measurement is no doubt of value to the physiologist, but to those concerned in physical education it is practically useless. Many of the results do not accord with what would be inferred from practical experience, nor can they be put to any practical use. The amount of muscular expenditure incurred in rowing one mile at racing speed is said to be represented by 18·56 foot-tons. But walking a mile at an ordinary pace causes an expenditure of 17·67 foot-tons, from which it must be inferred that there is very little difference between these two forms of exercise, so far as the use of the muscles is concerned. Those who are interested in athletic matters would not be able to recognise the correctness nor the value of these estimates, especially when they are compared with one another. Even when every allowance is made for the quickness of the stroke and the breathlessness induced by rowing at a racing pace, yet still it would be urged that the actual output of muscular force would be represented by a different figure when such exercise is compared with the walking of one mile.

Rowing six miles at racing speed would, upon the same estimate, be represented by 111·36 foot-tons, while walking the same distance would be expressed by 106·02 foot-tons—a result which makes the comparison still more marked.

So far as the present purpose of this paper is concerned, the terms 'excessive exercise' and 'unsuitable exercise' must be considered relatively, and with reference rather to the individual than to the actual physiological amount of muscular work expended.

What may be excessive or unsuitable exercise to one man may be moderate and quite excellent exercise to another.

In considering the phenomena of fatigue and the effects of any given exertion the estimate must be based upon the condition of the individual rather than upon the actual character of the work carried out. In this matter the age and bodily development of the man, the state of his general health, and the scope and extent of his muscular education play prominent and essential parts.

The effects which may follow upon excessive or unsuitable exercise, or upon exercise which, from the point of view of him who practises it, may be termed violent on the one hand and rash on the other, are very varied.

We have seen in the sections on breathlessness and on general fatigue what results may follow after severe exertion, so far especially as the respiratory functions and the general state of the body are concerned.

A sprint runner may fall senseless upon the path, succumbing to the results of his breathlessness.

A boy may remain completely 'knocked up' for several days after a paper-chase, and may be really ill and exhibit the febrile phenomena which have been already described.

There is no doubt that in not a few instances the pursuit of violent and extreme exercise has led to results which have had a permanent effect upon the health of the individual. In some cases an actual organic lesion has been produced; in others the body has been placed in a condition favourable for the development of disease; in a third series of instances there supervenes merely a feebler state of health.

The children of tubercular parents have acquired a spinal caries, or a diseased joint, as a result of injuries received through improper gymnastic exercises.

Children with a weak muscular system have acquired a lateral curvature of the spine through the pursuit of unsuitable exercises, which, so far as their spinal muscles are concerned, have been excessive and unequal.

It may be true, as is often asserted, that phthisis has appeared in those who are phthisically inclined, as a result of the strain and the exposure incident to severe exercises of endurance in the open air.

Many serious troubles may certainly be ascribed to acts of indiscretion and to exposure to cold and wet under trying circumstances during the pursuit of physical exercise; but such ills can scarcely be laid at the door of muscular training. The attack of acute rheumatism, which may have followed a long boating tour in the late autumn, may more justly be ascribed to camping out in the wet than to the effect of mere rowing.

Quite apart from any obvious lesion or disease, not a few individuals appear to suffer permanently in health as the result of some specific excess in the matter of exercise. A lad may 'knock up' after winning a three-mile race, and never be fit for much in the matter of athletics after that. A man of about middle age may, with probable reason, date a distinct and persistent decline in health to some one holiday in Switzerland, when he did more than his age and his condition justified.

Many inferences of this character may be unsound, but a few appear to be undoubted.

On the whole, however, it must be allowed that the injury which may follow, and no doubt has now and then followed, upon severe physical exertion represents but a small fraction when compared with the undoubted benefits which accrue from moderate and reasonable exercise.

Dr. John E. Morgan, of Manchester, in a work entitled 'University Oars: a Critical Inquiry into the Health of the Men who Rowed in the Oxford and Cambridge Boatrace, from 1829 to 1869,' has dealt with the effect of violent exercise, as illustrated by racing in boats, upon the general health.

His evidence shows that such exercise is, in the great majority of instances, no other than beneficial; that it is not a cause of disease or of premature death; and that, out of the large number of individuals dealt with, in only the insignificant proportion of 6 per cent. could any permanent ill effect

be claimed to have followed the pursuits of earlier years. In most of these cases even the evidence that rowing was to blame was indefinite or doubtful.

Mr. Walter Rye, the well-known authority on cross-country running, writes thus: 'We can speak from an experience now covering nearly twenty years, and can positively say that we know of no man of the hundreds with whom we have been acquainted who has been injured by distance running, and the rate of mortality among running men is singularly small.'

Similar evidence has been given by others with regard to forms of athletic exercise which may be considered to be violent.

Certain specific effects which may follow upon excessive or unsuitable exercise will now be considered.

The Heart and Blood-vessels

The heart has been ruptured during very violent exertion, as in attempting to lift or support an immense weight. This has happened to men of great muscular strength, but more often to the feeble, the ill-conditioned, or the aged.

Excessive exercise may lead also to hypertrophy of the heart, to dilatation of its cavities, and to valvular disease. The cases of hypertrophy appear to be most usual in the athletic, and in those whose employments involve constant severe labour—e.g. blacksmiths, miners, &c. In the matter of dilatation of the heart, Dr. W. Osler writes (Pepper's 'Medicine,' vol. iii. p. 631): 'Over-training and heart-strain are closely connected with the question of excessive dilatation during severe muscular effort. Both mean the same thing in many cases. A man, perhaps not in very good condition, calls upon his heart for much extra work during a race or the ascent of a very steep mountain, and is seized with cardiac pain and a feeling of distension in the epigastrium, and the rapid breathing continues an unusual time, but the symptoms pass off after a night's quiet. An attempt to repeat the exercise is followed by another attack, and, indeed, an attack of cardiac dyspnœa may come on while he is at rest. For months such a man may be unfitted for severe exertion or may be permanently incapacitated. He has overstrained his heart and has become broken-winded.'

Hæmorrhages of various kinds have resulted from, or have been ascribed to, violent exertion, and have been met with in almost all parts of the body. Cases of cerebral and of spinal apoplexy have occurred during extreme exertion, and Lagrange mentions an instance in which the spinal veins underwent rupture and led to paraplegia.

Aneurysm

The part played by exercise in the production of aneurysm is definite, but at the same time not necessarily predominating. In addition to violent movement come the factors of actual injury to the vessel, constitutional diseases, especially syphilis, and the conditions which lead to chronic arteritis. The author once saw a popliteal aneurysm in an acrobat of twenty-eight, who was in perfect health, and who considered it had been developed by the practice of hanging by the knees from one trapeze while he caught his companion, who was swinging from another. In this case great and well-localised pressure was exerted upon the ham. The form of exercise which appears to be most effective in the production of aneurysm is violent intermittent exercise, or sudden exercise when out of condition, or such actions as involve extreme movements of certain articulations.

Aneurysm is much more common in men than in women, and in the

labouring than in the favoured classes. It is noteworthy that in the etiology of aneurysm age plays a conspicuous part. Aneurysm is *not* most common at the age when violent physical exercises are most usually indulged in, but it is most frequent in individuals who have reached or have passed middle life. The occurrence of aneurysm under these circumstances affords another argument against the folly of violent and extreme exertion in men who are over thirty, especially when they are out of condition.

Varicose Veins

The frequently repeated statement that varicose veins in the lower limbs are produced and maintained by exercise is based upon very questionable foundations. It is said upon equally questionable grounds that those who indulge in running, bicycling, riding, or exercises involving long standing are in great risk of developing varicose veins. It is quite true that dilated veins are met with among athletes, runners, and bicyclists; but it has not been shown that the condition is more common among them than it is with other individuals. and, on the other hand, it is easy to produce any number of professional runners, athletes, gymnasts, and others who are constantly practising the very exercises which are said to produce varicose veins, and yet have not an enlarged vein in either of their lower limbs.

It is remarkable, moreover, that varicose veins are so much more common among women than among men, and that they are very often met with in women who take little or no exercise. There is, in fact, evidence to show that exercise has little if anything to do with the production of the disease; that the trouble is due to certain congenital defects in the vessels themselves, and that when such defect does exist muscular exertion may tend to increase the abnormal condition. This view is very strongly insisted upon by Mr. Bennett in his elaborate monograph upon 'Varicose Veins' (London, 1889). He shows that there is a distinct hereditary history in more than 50 per cent. of the cases. His cases prove that the trouble occurs in the active and the sedentary, in the weak and the strong, in the short and the tall. In females pregnancy and constipation play a conspicuous part in the etiology. Bennett is unable to connect the occupation of the patient in any definite degree with the actual production of the disease. While exercise probably has nothing to do with originating varices, it certainly tends to increase the trouble when it exists. Running, walking, jumping, cycling, and forms of exercise and recreation involving long standing are noteworthy in their ill effects upon varicose veins. Indulgence in these exercises would be unwise for those who are the actual subjects of the disease, but the fear of enlarged veins should never be an obstacle in the way of a free pursuit of the sports mentioned, nor can the possibility of varicose veins be legitimately urged as an argument against these sports.

The Lungs

Hæmoptysis and emphysema are stated to have been produced by violent exertion, and many chronic lung troubles have no doubt followed upon exposure and neglect during and after such exertion. Dr. Parkes states that congestion of the lungs may follow upon excessive or badly arranged exercise.

Bones and Muscles

Bones have been fractured by pure muscular violence, notably, the clavicle and humerus, but in the majority of such instances the bone has proved to have been diseased at the seat of fracture.

Violent exercise may lead to all kinds of lesions of the muscles. Muscles may be ruptured in whole or in part, tendons may be rent across or torn away from the bone, or may be displaced from the grooves in which they lie. In many instances the subject of these lesions is out of condition, or is in feeble health or aged, or is suffering from definite disease.

The Hon. E. Lyttleton well says ('Health Exhibition Manuals,' vol. x. p. 121): 'To an athlete the first premonition of coming old age is to sprain himself somewhere.'

Muscles which are over-exercised for a considerable time waste and become soft. The legs of professional runners are occasionally quite atrophied from over-use of the muscles of the parts.

The abuse of certain movements and the excessive repetition of the same may lead to some permanent contraction of the muscles concerned. Thus in professional gymnasts who use the flexors of the arm to excess the elbow may be found to be a little flexed and full extension of the joint to be impossible. Sailors on sailing vessels who are constantly holding or hauling ropes not infrequently develop a condition of the hand which prevents full extension of the fingers.

The finer muscles when unreasonably employed may become the subject of such nervous changes as are illustrated by writer's cramp and other forms of spasm incident to certain employments.

Joints may be injured by violent exertion. Synovitis may follow upon over-use of an articulation, and one very common accident among the athletic is a displaced semilunar cartilage in the knee-joint.

Certain deformities of the body may follow restricted and often repeated exercises and the excessive employment of certain muscles. Gymnasts who have developed to an extreme degree the muscles of the upper limbs and upper half of the trunk have a rounded back in addition to their unwieldy shoulders.

Fencing tends to produce a lateral curvature of the spine with (in right-handed fencers) the concavity of the curve to the right. The author has observed a permanent degree of lordosis in an acrobat who produced extraordinary results by his power of bending the body backwards at the lumbar region.

Hernia

The influence of muscular exertion in the etiology of hernia is so fully dealt with in the ordinary text-books of Surgery that it need not be considered at length in this place.

In cases of congenital hernia and in such other forms as depend upon defects in the vaginal process of the peritoneum, and in those instances of hernia generally which are met with in young children, the rupture is made manifest by some expulsive effort as a rule, and not by any movements that can be considered as constituting exercise.

Acquired herniæ are beyond doubt produced by forces tending to cause the intestines to protrude.

Violent effort is a recognised factor in the production of these ruptures. It is very rarely indeed, however, the sole factor. Certain anatomical conditions are present which render a hernia possible in one man and almost impossible in another.

It is noteworthy that the main safeguard against hernia is a perfect and vigorous muscular development. The greater number of examples of acquired hernia are met with, not only in men of imperfect muscular development, but in individuals who are out of condition. Such herniæ are commoner in

those who return to laborious work after an illness or when in feebler health, in men who undertake heavy work without any preliminary training, in persons who by reason of their age or their habits are losing muscular tone, are becoming coarse, soft, and flabby, are developing fat within the abdomen, and who exhibit the phenomena of relaxed tissue. Gymnasts and acrobats, in spite of the immense muscular efforts they put forth, are seldom the subjects of hernia. If they become ruptured the hernia will appear late in their career, at a time when they are falling off and losing tone, or at any period when they are out of condition and out of training.

Carefully selected, systematic, and well-graduated exercise is the best protection against hernia, and the objections against athletics founded upon the production of hernia are unjust and unsound. An acquired umbilical hernia is unknown in muscular men with firm abdominal walls. It is common in those who have large, flabby, and pendulous bellies and who take no exercise at all. So far as acquired hernia is concerned, it would be more accurate to state that rupture is due to want of exercise rather than to excessive indulgence in the same.

TRAINING

With 'training' in the sense of preparing the body for athletic competitions and great feats of endurance the present article has no concern. The subject may be considered only in so far as it throws light upon the mode of living which may be observed by those who are anxious to get themselves into condition and to take a considerable amount of moderate exercise.

Upon this subject a number of books, pamphlets, and articles have been written, and, it must be confessed, a great deal of nonsense promulgated.

Strange elements of superstition and gross ignorance have entered into the older methods of training, and there are still professional athletes who keep the details of their training secret or who ascribe their success to some article of food or some particular rite or observance.

The old system of training was quite remarkable. The unfortunate man had his weight reduced by profuse sweating, especially by walking and running in thick and heavy clothes. He was purged every day, he was almost starved in the matter of water, and took sparingly of old ale, spirits, and port. He lived mainly upon half-cooked beefsteaks and bread, and was encouraged to gorge himself upon this monotonous diet.

Matters are now entirely changed, so far, at least, as amateur athletes are concerned, and without entering into detail as to the exact methods practised by one modern system or another, the general features of a reasonable mode of training may be briefly discussed.

In the first place, time must be considered. 'A man of twenty-five and upwards,' writes Mr. Woodgate, 'who has been lying by for months, or it may be for a year or two, can do with three months of training. The first half should be less severe than the last. He can get into "hunting" condition in the first six weeks and progress to "racing" condition in the succeeding six. University crews train from five to six weeks. College crews cannot give much more than three weeks to train for the summer bumping races.'

During training a man's life must be as regular as a clock: his meals must be taken to the minute, his exercises must be systematised and so adjusted as to be progressive and well-timed. He should retire to bed early and rise early, should sleep in a well-ventilated room, should bathe night

and morning, should be particular as to the kind of clothing worn, and take every precaution to avoid cold. In all things he should be moderate and methodical. His meals are best represented by a substantial breakfast, a light lunch, a still lighter tea, and a substantial dinner in the evening when his day's work is over. He should take plenty of sleep. He should rest after each meal. Smoking should be absolutely forbidden, and no form of alcohol should be allowed. There is overwhelming evidence to support the practice of training upon water. In the matter of diet a man should be moderate, should not gorge himself, and should, within certain limits, consult his own taste in the selection of food.

He will do best with the most easily digested foods, and may take beef, mutton, chicken, fish, and game, while he should avoid pork and veal and lobster and other well-accredited producers of dyspepsia. He should under no circumstances be debarred from eating fat and butter. A man in training needs a good supply of carbon in his food.

It is well to avoid much sloppy food, such as soups and broths, to be very moderate in the consumption of starchy foods and of sugar, to avoid coarse vegetables and large quantities of potatoes. Some green vegetables and some fruit should be taken every day. It is needless to say that he should avoid pastry and sweets and the confused and uncertain forms of food known as entrées. Cheese may well be omitted from his dietary and salad take a constant place. Meat will be eaten at breakfast, lunch, and dinner.

In the matter of liquids, he should not drink for the sake of drinking. He should take as much only as is needed to quench his thirst, and he should not consider the time of his drinking. The custom of allowing men to drink only a certain quantity of water at certain fixed times of the day is obviously silly. A man should drink when he is thirsty, and should not be compelled to suffer with a parched mouth simply because the drinking hour has not come. Men differ immensely in the quantity of fluid they need. The matter cannot be settled by rule. It may be taken as certain that the least quantity is consumed when taken in small amounts, and often, and not when the individual has been tortured with thirst and swallows a quart or more when his time for drinking comes.

Under a reasonable and liberal system of training no man should break down or become, as the expression goes, 'stale.'

The old system of training was rather a test of strength than a means of developing it, and those who train in modern times should make themselves familiar with the follies of those who trained in days gone by.

SPECIFIC EXERCISES

Walking

is the most usual, the most simple, the most easy, and one of the most valuable modes of taking exercise. It is suited for individuals of all ages and of all states of development. It is the main exercise of the quite young child, a prominent feature in the training of the athlete, and usually the only form of exercise indulged in by the aged.

It is a mode of exercise which requires neither apparatus nor special locality, and there can be few so engaged in the pursuit of living as to find a legitimate excuse for not indulging in this simple means of keeping the body in health.

While walking exercises mainly the muscles of the legs, it brings into

play also the muscles of the loin and of the back and abdomen. Not only has the individual to move, he has also to keep erect. The circulation and respiratory movements are increased, and the general beneficial effects of exercise are brought about.

The actual mechanics of walking and the precise nature and extent of the movements involved are admirably illustrated by the photographs published by Mr. Eadweard Muybridge, of Philadelphia. Certain of these are reproduced with a very lucid explanation in Keating's 'Cyclopædia of the Diseases of Children' (vol. iv. 1891).

Walking is distinct from marching, in which a less easy attitude of the body is maintained. Other things being equal, slow walking is more tiring than walking at a moderate pace.

It is important that the style of walking be cultivated, that the spine be kept straight, the head erect, and the shoulders well back. An easy and perfectly graceful mode of walking is not common among civilised people. The countryman rolls along walking from his hips, the over-dressed lady steps stiffiy and gingerly like an automaton, the untrained lad slouches in a manner well termed slovenly.

A purposeless walk, such as is the common exercise and often the only exercise in ladies' schools, where the pupils walk in procession, side by side, over a stated distance, is somewhat depressing and does not develop the exercise to its fullest. Walking with an object represents the best and most pleasant form of this element in physical training. Shooting involves, not only the delights and excitement of sport, and the use of the hands and arms, but also a long walk over often irregular and difficult ground. The admirable game of golf, which is said to date from the time of Edward III., represents one of the very best forms of walking with an object. This game has a fascination both for the young and the old, and is one of the most perfect and in every way the most admirable form of exercise for men who are past middle life or have reached old age.

Walking races are contests more or less of endurance, and test rather the staying powers than the skill or the muscular strength of the competitor. Many professional walkers walk vilely. In walking for a race 'it is absolutely necessary,' writes a great authority (Mr. Shearman), 'to have the muscles so hard all over the body that "knocking off" for any space of time becomes fatal to all chances of success.'

In walking competitions the mile has been covered in 6 min. 23 sec., three miles in 20 min. $21\frac{1}{2}$ sec., twenty miles in less than 3 hours, and fifty miles in less than 8 hours.

Running

is the exercise for children and young people. It employs the muscles of nearly the whole of the body and, by increasing the rate and depth of the respirations, is an admirable element in developing the chest. Children appear to be the subjects of an irresistible impulse to run, an impulse that should never be checked.

Running has been described as a succession of leaps. It undoubtedly has a most beneficial effect upon the circulation of the viscera, strengthens the heart, when indulged in in moderation brings out the individual's powers of endurance as well as his strength and his capacity for rapid movement.

Muybridge's photographs show the mechanical details of the act of running very clearly. A reproduction of two of these photographs in Keating's 'Cyclopædia' (*loc. cit.*) may be advantageously consulted.

Running, to any extent, as an exercise is not advisable after the age

of thirty, nor in those who have not kept themselves in practice and in sound condition. In the aged it may be ranked often as actually dangerous. The best ages for running are between eighteen and twenty-five, and upon few forms of athletic exercise does age tell more certainly and accurately than in this.

So far as athletic excellence is concerned, it may be said that a runner is born, not made. There are many who would never attain a first position as runners in spite of unlimited practice. Sprint running or sprinting is the term applied to running a short distance at top speed without a break. Three hundred yards is considered to represent the limit of sprinting distance. 'In sprinting,' writes Mr. Shearman, 'the front muscles of the thigh which bring the leg forward are the most important factors for speed, as it is on the rapid repetition of the stride that the main result depends; in the running of longer distances the back muscles of the thigh, which effect the propulsion, bear the chief strain. Both sets of muscles are, of course, used in every race, but the longer the distance the less important the front muscles become.' The sprinter, however, runs rather with his lungs and heart than with his legs. Breathlessness is *the* difficulty with which he has to contend. Thus it happens that the sprinter may be tall or short, may be a feather weight or scale at 13 stone, may have limbs like a deer or calves which would cause the envy of a footman.

Long-distance running is a matter, not only of strength, but also of endurance and lung power. Some of the best long-distance runners have been short men, very strong, light of weight, and with large and deep chests.

Hare and hounds and the paper-chase form most exciting and admirable forms of running. The sport, however, is only open to those who are young, who are in perfect condition, and who have increased the distances they have run from time to time by gradual steps.

For children a hoop forms one of the most popular means of giving a purpose to running and of infusing interest into what in the abstract is a somewhat monotonous form of exercise.

On the racing track 100 yards has been covered in 10 sec. and 300 yards in 30 sec. A mile has been completed in 4 min. $12\frac{3}{4}$ sec., three miles in 14 min. 29 sec., twenty miles in a few minutes short of two hours, and fifty miles in a little short of six hours.

Jumping,

like running, has certain very definite age limits. Jumping in competitions is limited to individuals under thirty or more usually under twenty-five. Twenty may be taken as the best age. In jumping, the muscles of the lower limb are of course mainly employed, but in addition to these it will be noticed that nearly every muscle in the body is in action as the leap is taken. The details of the movement are well shown in Muybridge's photographs (*see* Keating's 'Cyclopædia,' vol. iv. photo v.).

A jumper of any excellence is, like a runner, born, not made. Celebrated jumpers, especially long jumpers, have been of almost any size and weight. W. B. Page, who cleared a height of 6 ft. $3\frac{1}{4}$ in., was only 5 ft. 6 in. in height.

Jumping as an element of physical education has some especial points of value. It encourages very vigorous, instantaneous, and well co-ordinated muscular contractions, and cultivates that form of muscle intelligence which is called spring.

I am of opinion that jumping is not quite the exercise for women or for young girls who have passed the period of puberty. Certain uterine troubles have with some show of reason been ascribed to an indulgence in this exer-

cise. For flabby people and young subjects who are disposed to be stout, and for any who are not in very sound condition, the exercise is not without risk. It may well be left to lads and to youths in the prime of athletic life.

In the high jump 6 ft. $3\frac{1}{4}$ in. have been cleared, and in the long jump the remarkable distance of 23 ft. 2 in.

Allied to jumping must be considered the exercise of skipping. A more admirable and more perfect form of exercise, considering its simplicity, could not be practised. It employs the muscles, not only of the legs and loins, but also of the back, abdomen, and neck, and even the muscles of the arms; it especially tends to strengthen the ankles and knees and the arches of the foot; it is admirable for children with weak backs; it increases the respiratory movements to a marked extent; and if practised upon grass and in the open air it is one of the most perfect forms of exercise for young girls that could be devised.

Those who consider skipping too simple and too trivial to form a serious element in a physical education may be surprised to know that many athletes and gymnasts, and notably, it must be owned, prize fighters, take a very large part of the exercise prescribed during training by means of the skipping-rope.

It would be well if those parents who consider that nothing in the way of physical training can be done without a gymnasium or a drill-sergeant would invest in a hoop and a skipping-rope and take note of the effect produced by these simple means.

A skipping competition upon a lawn or in a field is, when kept within limits, one of the most perfect forms of recreation a girl can indulge in. It should be carried out in slippers or light shoes, and if it were a little more popular the feeble ankles and flat feet which are so common among girls and women would certainly be less often met with.

Skating

is another admirable exercise, especially valuable from the fact that it can be practised at a time when few forms of outdoor recreation are possible, and when girls and women are apt to sit at home and huddle over a fire or weary themselves by dancing, until the small hours of the morning, in a heated ballroom.

Skating is a form of modified walking, but it calls into play a greater variety of muscles. The balance has to be maintained and the muscles of the abdomen, back, and loins have much to do. It is exhilarating, it is admirably adapted for persons of almost all ages, and is as well suited for females as for males; it comes at a time when the want of exercise in the open air is probably telling upon the health and spirits; it tends to give an easy and graceful carriage to the body; it strengthens the ankles and is a fine antidote for the flimsier form of nervousness. No mode of progression upon the feet is more delightful, easy, or invigorating. In a country house when every form of indoor amusement has been exhausted, when the roads are too dirty for walking and the ground too heavy for pleasant riding, a hard black frost comes as a boon, and the manner in which the young and the old, the strong and the frail, turn out and hurry to the ice gives the impression that the instinct for exercise in human beings is as strong as the impulse which leads the duckling to the water.

In racing, the following distances have been covered in the times named: 100 yards in 10 sec., one mile in 3 min. 26 sec.; three miles in 10 min. 33 sec., twenty miles in 1 hr. 14 min.; fifty miles in 4 hrs. 13 min.

Riding

is a mode of taking exercise and fresh air which is not open to all, and is within certain narrow limits denied to the inhabitants of cities.

The muscles exercised in riding are those mainly of the adductor segment of the thigh and of the back. The movement undoubtedly improves the visceral circulation and affords a remedy for hepatic congestion and constipation; it promotes a deeper respiration and a more active pulse; it combines in a remarkable manner both active and passive movement and is a specific for the dyspepsia and other ills which attend a sedentary life; it provides a means of strengthening the spine, and it should be remembered that a good 'seat' implies rather the power of keeping the trunk well balanced than the power of gripping the saddle with strong adductor muscles.

It is a pursuit that can be indulged in from childhood to old age, and it is one of the most popular forms of exercise among Englishwomen.

Children should learn young and should be well taught. The exercise is not good for girls with commencing lateral curvature, nor should it be taken up by children who have 'outgrown their strength,' and are tall, weedy, and of feeble muscular development, until the muscles have been strengthened by other methods. Overgrown girls who indulge in no other exercise but riding are apt to become round-shouldered and round-backed and to acquire a very ungraceful seat. Lateral curvature of the spine is certainly often induced and fostered by riding.

In any instance a young girl should be taught to ride upon either side of the saddle, and this precaution should be especially observed in the case of those who are supposed to have weak backs. After a very long ride a man feels most tired in the lower part of his spine, and is very disposed to loll in the saddle. In a young girl the most important muscular strain comes upon the back, and is concerned in keeping the body erect.

It is not uncommon to see girls, who have been badly taught, riding with the body much bent to one side or with the spine 'all in a heap' and in the attitude of cyphosis. Riding is not the best kind of exercise for the round-shouldered and for such girls as have unequally developed chests.

Horse exercise, so far as ladies are concerned, is a little hampered by the fashion which demands that a riding habit shall fit like a glove and that, as a consequence, the waist should be compressed so as to reach fashionable proportions. The long skirt of the riding habit adds not a little to the danger of horse exercise for women.

Riding forms an admirable exercise for men who have reached or have passed middle life, and the saddle is very often the last thing that an old sporting man relinquishes as infirmity creeps on.

Professional horsemen (grooms, postilions, jockeys, &c.) are apt to develop a certain deformity of the lower limbs and back. The legs tend to become concave or bowed, and seem often to have been stunted in growth. The back—especially in jockeys—tends to become arched and rounded and the shoulders high. An old ostler and an old jockey have often a quite characteristic figure and attitude.

The deformity, such as it is, is evidently the result of style in riding, as it is not observed in artillerymen and other cavalry soldiers.

Swimming

should be taught as a matter of routine to every child, and it is a disgrace to this country that this very simple accomplishment is so rare. Swimming

is easily learnt at any age, and when once mastered is never forgotten. It is acquired nearly as quickly by girls as by boys, and the first lessons may be given between the ages of eight and ten.

Swimming calls into use a new set of muscles or rather a new combination of muscles. In the early struggles of the learner an immense amount of force is expended in carrying out the unaccustomed movements. As proficiency is attained the movement becomes easier and easier, until it is as simple as walking, and the limits of the swimmer's powers are restrained rather by the temperature of the water than by his muscles.

Few modes of exercise are more enjoyable, especially when practised in a broad river or the open sea.

The muscles of both the upper and lower extremities are concerned, and to a lesser degree the muscles of the back and abdomen. The scapular muscles, the deltoid, the pectorals, and, above all, the latissimus dorsi are especially employed in swimming. The arms tire before the legs, and the sense of exhaustion is always experienced most about the shoulder.

Work in a gymnasium is an excellent means of developing the swimming muscles, and, so far as long distances are concerned, the chief factors are strong arms and a good chest.

Swimming increases the respiratory movements and straightens the back. The movements of the limbs are very free, and afford a striking contrast to most of the other forms of exercise which concern the lower limbs.

Swimming should be well taught. Considering the facilities afforded in this country for acquiring the art, it is astounding that among those who do swim a fine and easy style of swimming is so rare.

Probably some 70 per cent. of those who can swim can just 'swim a little,' and can do not more than keep themselves afloat by extravagant movements for fifty or 100 yards.

I do not think that the practising of the swimming movements on land is of much value, although it forms a great feature in the gymnastic course in France.

The most remarkable swimming feat was that of Matthew Webb, who swam from Dover to Calais in 21 hrs. 45 min. In a race 100 yards has been covered in 1 min. 6 sec.

Fencing

In the Badminton Library volume on Fencing the history of this art is detailed, together with the circumstances and manner of its development, and to the account is appended a quite remarkable bibliography of the subject.

Fencing as it is at present practised is an extremely scientific, precise, and highly elaborated art. It is no mere slashing with a protected foil. Every move has been systematised; every method of attack and defence has its individual name. The movements are as complex, and yet as well defined, as the movements of the men upon a chessboard. No mode of exercise has reached a more elaborate degree of finish. Fencing is pre-eminently an exercise of skill. Considerable employment is given to all the muscles of the body, to the lower limbs, and to the back, but principally, it is needless to say, to the right or sword arm. The beginner will after his first few lessons ache from head to foot. He will believe that he has been fencing with every muscle he possessed, a belief which will be well founded. As, however, he becomes more proficient he will feel that the strain falls to a great extent upon the right upper extremity.

Fencing is as much an exercise of the brain as of the muscles. He who

has acquired some proficiency in the art will find that he becomes tired in his brain and cord rather than in his limbs. The bout induces rather a nerve than a muscle fatigue.

Fencing develops certain faculties in an admirable manner. It requires quickness of eye, extreme readiness of action, accurate muscular sense, great precision and fineness of movement, and perfect powers of ready co-ordination. It involves the practice of a quick decision, a rapid judgment, and a good memory. A fool could never become a good fencer, even if he were endowed with the most excellent physical qualifications.

Fencing has become more popular of late years, and is an excellent exercise for busy men. It is to be regretted that the practice often takes place in somewhat ill-ventilated rooms. Fencing for elder children and for ladies forms, as it is usually practised, but a somewhat imperfect development of the proper art. It is not the exercise which would be recommended to excitable, nervous, or overworked children. It is better adapted for those who appear to be apathetic and dull. A dull boy will find a fencing lesson an infinitely greater 'fag' than whole pages of irregular verbs.

It should never form for children, or, indeed, for adults, an exclusive or even predominant form of exercise on account of the unequal muscular development it encourages. It is well suited to encourage in lads and in elder girls a good carriage, free movements, a lissom and graceful attitude of the body, great agility, and both muscular and mental quickness. If it is possible to make an individual 'sharp,' fencing may be considered as capable of doing it.

The exercise must be recommended with great care. It would be injurious to those who have a disposition to lateral curvature, and to any who are the subjects of unequal muscular development.

In the physical education of the young it can occupy but a small space. It is a perfect exercise for adults, especially for men who lead sedentary and monotonous lives. Dr. Lagrange asserts that 'everyone who has fenced *much* shows, in a more or less pronounced degree, a lateral curvature of the spine.' In right-handed fencers the concavity of the curvature is to the right, in the left-handed to the left. The shoulder of the arm which holds the foil is lowered. Dr. Lagrange founds his conclusions upon the examination of twenty experienced fencers. The tendencies to deformity are very unequally marked. In some the deviations are quite trivial, in others they are pronounced. This evidence is of considerable importance in forming an estimate of the value of fencing as a muscular exercise, especially to those who are under twenty or twenty-five years of age.

Boxing,

if carried out under proper conditions, and especially if practised in the open air, is an admirable exercise for lads and young men. Unfortunately the surroundings of a boxing saloon are not always the best adapted for the education of youth, and the so-called 'professors' of the art are not usually the best associates for plastic-minded lads.

The exercise itself, however, is admirable. It brings into play practically all the muscles of the body. A vigorous blow is struck as much from the leg and trunk as from the arm. It has been well said that a good and powerful blow starts from the foot. Mitchell, in the monograph upon boxing in the Badminton Library series, says: 'It may seem paradoxical and provoke a smile to say that the first necessity for using the fists properly is to understand the use of the feet.' The boxer needs to be agile,

to be able to use his legs, to be quick with the movements of his head and his trunk. Boxing, moreover, gives excellent use to the left arm, which is apt to be neglected in many other forms of exercise. It calls for rapidity of movement, ready decision, good judgment, and a control of the temper. It promotes the circulation, and in a vigorous round the boxer is very soon rendered breathless.

The atmosphere in a boxing saloon is not always so well supplied with fresh air as it might be.

Boating

It may perhaps be said, without fear of contradiction, that boating presents one of the most complete, uniform, and delectable forms of exercise. It is an exercise which is especially associated with the English, and it is in England that the sport is the most highly elaborated and the most widely practised. Boats of one form or another appear among the environment of such primitive peoples as have lived by the sea or about the banks of navigable rivers; but the development of boating as a fine art, the perfecting of this picturesque and enjoyable mode of locomotion, rests with the sturdy and water-loving sons of England. Surrounded on all sides by the sea, and living in a land permeated by many rivers, it is not unnatural that an English lad should take to the water like a duck, and should feel that enthusiastic love for the sea which appears to be almost an hereditary taste, and which is possibly not a little influenced by the great naval records of the country.

For every professional rowing man in our midst there will be hundreds of amateurs who are by no means a discredit to the sport. At all public schools situated within reach of water, rowing is a prominent feature of school life. At the two great Universities of Oxford and Cambridge boating occupies a position which the less robust section of the public are apt to consider a little too conspicuous. The whole length of the Thames from Oxford to London during the few months of the English summer is alive with boats, and is animated by rowers of all classes and all ages. Among this busy, sunbrowned, and white-flannelled community may be seen old men and maidens, as well as young men and children.

The sheer delight given by the mere circumstances of boating requires little comment. It needs merely the conception of a stretch of fair water, the early morning of a day in the English summer, a light outrigger, and a pair of sculls to every point of which the sculler has fitted his muscles. There is the crisp grasp of the water, the swish of the blades, the shooting of the tiny craft across the polished river, the whistling of the wind about the rower's head, and the rippling of the water as the prow runs through the magic lights and shadows which are thrown from the bank.

Boating offers, moreover, one of the most charming forms of touring. A man may spend many summer holidays in a boat or in a canoe before he has exhausted the beauties of the rivers of Great Britain.

Across the Channel the system of canals on the Continent offers an unparalleled opportunity for a journey such as has been described—as no other pen could have described it—by R. Louis Stevenson in his 'Inland Voyage.'

It is greatly to the credit of England that her waterways are more densely peopled with boating folk than are the waters of any other country of like population.

With regard to boats, it is only necessary to say that for racing the keelless boat is employed. Its bottom is round and smooth. Such a boat is extremely unsteady and requires all the skill of a novice to 'sit it.' The

beginner may find no difficulty in propelling such a boat, but he will experience considerable difficulty in keeping in it. The sculler in a racing boat has, like the bicyclist, first to balance himself and then to move.

The outrigger was introduced in 1842 by Clasper.

This very simple improvement enables a greatly increased length and greater advantage in leverage to be given to the oars, while at the same time it allows the dimensions of the racing craft, and especially of the beam, to be much reduced. The ordinary length of an inrigged pair-oared pleasure boat or gig is 22 ft. and the beam 3 ft. 9 in. The length of a racing sculling boat will be about 31 ft. and the beam about 11 inches.

Another noteworthy improvement—the invention of an American—was the sliding seat, which was first used in England in a race in 1871. The general features of the sliding seat will be sufficiently familiar. Its precise mechanical value has been very ably described by the Rev. E. Warre, of Eton, in the following words :—

'Mechanically speaking, in rowing the water is the fulcrum, the boat is the weight to be moved, the oar is the lever, and the man applies the power. The leverage is most powerful when applied at right angles to the weight; but in the problem to be solved, owing to the motion of the oar itself through the water and the motion of the boat through the water, the moment at which this can be the case is extremely transient. Could any satisfactory mechanism be devised by which the weight—that is, the thowl against which he rows—could be moved forward during the stroke, while the oarsman was still in the position to exert his full power against it, we might expect a great increase of speed. This, however, is a structural problem not yet solved. But the sliding seat in some measure answers the purpose by enabling the oarsman or sculler to continue his physical effort by the straightening of his legs in such a way that his power and his weight, which are most available at the beginning of the stroke, are operating in the water for a longer period during each stroke than could be if he were on a fixed seat. The gain is much less than that of a moving rowlock would be because, owing to the rising of the knees when the slider is forward, a man cannot obtain a much greater reach forward than he could on a fixed seat. It is when the body has moved up towards the perpendicular, and the water has already been got hold of, that the advantage of the sliding seat begins. As the slider moves back, the uncoiling of the human spring, which is imbedded in the stretcher, can go on with undiminished force for the distance of the slide, when the pressure of the legs ceases and the weight of the body is again entirely thrown on the seat. The mechanical advantage is here mostly after the rowlock, and that is the least valuable part of the stroke, especially in a light boat. Still the gain is considerable, as it enables more weight and more strength to be applied to the oar for a longer portion of the stroke.

'Further, there has been for grown men a physical gain in that the increased length of stroke enables the same pace to be attained with fewer strokes per minute. The pace of the inferior or mediocre crews accordingly has been improved. Moreover, the effort of springing the body forward to its fullest reach, which on the fixed seat was necessary, is now greatly reduced by the mechanism of the slide, and consequently the exertion to heart and lungs is much less. This is a gain to those who, by reason of age and figure, are not so lithe and active as in boyhood, but it has been a loss to public school crews, who could make up formerly by pace of stroke and agility for their inferiority in strength to men.'[1]

[1] *Health Exhibition Handbooks*, vol. x.

The sliding seat is estimated to give a gain of about 18 in. in the length of the stroke upon a 9 in. slide.

'The sliding seat,' writes Mr. Woodgate, in the Badminton Library volume on Boating, 'decidedly relieves the abdominal muscles and respiratory organs during the recovery. The point wherein a tiring oarsman first gives way is in his recovery, because of the relative weakness of the muscles which conduct that portion of the action of the stroke. It therefore is obvious that any contrivance which can enable a man to recover with less exertion to himself will enable him to do more work in the stroke over the whole course, and still more so if the very contrivance which aids recovery also gives extra power to the stroke.'

The increase in speed has not been so great as might have been imagined.

Rowing and Sculling

Rowing, it is needless to say, involves the pulling of one oar with both hands, and sculling the pulling of a pair of sculls, employing, of course, one hand to each.

The details of the stroke in rowing should be well understood in order that the muscular features of the act might be recognised and the qualities of a good stroke appreciated. The following description of the rowing stroke by the Rev. E. Warre is precise and lucid, and can hardly be improved upon :—

'The moment the oar touches the body drop the hands smartly straight down, then turn the wrists sharply and at once shoot out the hands in a straight line to the front, inclining the body forward from the thigh joints and simultaneously bring up the slider, regulating the time by the swing forward of the body according to the stroke. Let the chest and stomach come well forward, the shoulders be kept back, the inside arm be straightened, the inside wrist a little raised, the oar grasped in the hands, but not pressed upon more than is necessary to maintain the blade in its proper straight line as it goes back, the head kept up, the eyes fixed on the outside shoulder of the man before you. As the body and arms come forward to their full extent, the wrists having been quickly turned, the hands must be raised sharply, and the blade of the oar brought to its full depth at once. At that moment, without the loss of a thousandth part of a second, the whole weight of the body must be thrown on to the oar and the stretcher by the body springing back, so that the oar may catch hold of the water sharply and be driven through it by a force unwavering and uniform. As soon as the oar has got hold of the water, and the beginning of the stroke has been effected as described, flatten the knees, and so, using the muscles of the legs, keep up the pressure of the beginning uniform through the backward motion of the body. Let the arms be rigid at the beginning of the stroke. When the body reaches the perpendicular, let the elbows be bent and dropped close past the sides to the rear—the shoulders dropping and disclosing the chest to the front, the back, if anything, curved inwards rather than outwards, but not strained in any way. The body, in fact, should assume a natural upright sitting posture, with the shoulders well thrown back. In this position the oar should come to it and the feather commence.'

Among the particulars to be noted in the stroke are the following. The back should be set stiff and must not yield as the stroke is pulled. It should be straight while the chest comes well forward. The whole trunk should swing as a rigid column from the hips, moving forwards and backwards. The main pull of the arms is from the shoulders. The biceps

should not do the work and the elbows must be kept well to the side. If this latter point be insisted upon the stroke can scarcely be rowed home by the arm muscles. When an oarsman is becoming 'pumped' it is in the recovery that he feels the strain. He fails to shoot the hands forwards from the chest the moment after they touch that point, and he becomes sluggish in reaching forward to take a fresh hold of the water.

Sculling is in all essential particulars identical with rowing, so far as the muscular movements are concerned. It involves, however, more precision, more skill, more practice. The sculler has to acquire the art of balancing himself, and a failure to ever do this well leads often to a fixed bad style, which no practice appears to remove.

The remarks already made apply to rowing and to sculling in its highest developments, but in all essentials they apply to the ordinary pleasure boat. In such a boat there is no need of great speed, there is no sliding seat to embarrass an already complex movement. The boat is steady enough, and the oarsman can devote all his energies to the pulling.

It is much to be regretted that many boating men and women are content simply to pull the boat along. They care nothing about the order of their going, they are perfectly indifferent as to style, and are content for the rest of their days to row badly. To row correctly is to row with ease. The better the style, the easier the movement and the better the pace. The better the style, moreover, the more complete and perfect is the exercise. Bad rowing is often bad exercise, and to row in the atrocious manner with which some holiday makers have made us familiar is to indulge in a pursuit of very doubtful utility.

As an exercise, sculling may be considered to be better than rowing. To all ordinary individuals boating should imply a knowledge of sculling, and no person should be content with the capacity to pull one oar.

Sculling involves a more even employment of all the muscles of the body; one side of the body is not more extensively employed than is the other; there is no disposition to rotate or 'screw' the back or to pull, as it were, from one side. In sculling, the muscles of the two sides of the body are equally employed and the exercise has the great merit of being perfectly symmetrical.

The Muscles Involved

Let us imagine a man sculling in an ordinary gig with a fixed seat. He takes a good grasp of the sculls, using fully the muscles of the hand and of the flexor side of the forearm. He throws the hands forwards to take the stroke, using the extensor muscles of the arm, the pectorals, the serratus magnus and such scapular muscles as draw the upper limb forwards. The body is at the same time thrown forwards by the contraction of the abdominal muscles, the psoas and iliacus, and some of the anterior femoral muscles. The whole back is kept stiff, and the trunk swings forwards from the hip joints only. The sculls are now drawn through the water, the muscles of the upper arm contract, together with the posterior scapular muscles and the latissimus dorsi. The main agent, however, in effecting the stroke is provided by the great mass of the extensor muscles of the back and by the powerful glutei muscles. The man rows with his back, not with his arms. In pulling he presses the feet against the stretcher, contracting nearly all the muscles of the lower limb. In feathering he calls into action the extensors of the forearm.

Inasmuch as the head is kept erect and the chest well thrown forward, it will be seen that sculling and rowing do actually engage all the main muscles of the body.

If a sliding seat be employed, then the exercise is still more complete and uniform, for the muscles of the lower limb are used to a still greater extent in drawing the body forwards and in shooting it back. Still the main strain in rowing and sculling falls upon the muscles of the back and hip.

The mechanics of sculling can be readily studied in Muybridge's ingenious photographs, and reference may be made to the description in Keating's 'Cyclopædia' (vol. iv., photo. iv.).

The idea, often expressed, that boating involves the use of the arms only is even more ridiculous than the equally common assertion that bicycling involves the use of the legs only. A muscular man going into hard training for rowing will find that his biceps muscles will actually diminish in size.

The bad oarsman rows or sculls with his biceps. Such an individual is often to be seen in the London parks. He sits with his back limp and arched, and very probably with his legs tucked away under the thwart. He leans forwards to take the stroke, grasps the water, and pulls the sculls through simply by the action of the muscles of the upper limb and mainly by the biceps. He does not extend the trunk beyond the perpendicular, and the manner in which he projects his elbows has been caricatured often enough. The movements he executes are not those of the oarsman, and, although the half-hour's pull may be better than no exercise at all, it tends to make the individual round-shouldered and clumsy, and to develop the muscles of his arms to the sacrifice of all the others.

The Adaptabilities of Boating

Boating properly carried out must remain one of the most perfect forms of muscular exercise we possess. The degree of muscular effort involved can be regulated to any degree, and a girl of eleven may scull with as much style as an athlete of twenty.

Boating is an exercise which does not cause breathlessness. An elderly man can pull a boat day after day on a long river tour without difficulty, provided the pace be moderate, when he would be utterly out of breath on ascending a hill or even a great flight of stairs. It can be indulged in by individuals with weak hearts and weak lungs, provided, of course, that the pace is strictly limited.

Boating is not suited for the subjects of hernia nor for those with a disposition to hernia. The posture assumed in leaning forwards to take the stroke and the contraction of the abdominal muscles at the same time favour a hernial protrusion.

Boating, however, tends to develop and to strengthen the abdominal muscles and to lessen the size and improve the tone of the pendulous abdomen not uncommon after middle life.

Rowing and sculling are admirable exercises for girls and women. Ladies should row without corsets, or with corsets of the slenderest possible make. Perhaps no exercise is better suited to remedy the muscular defects which are conspicuous in the gentler sex. It expands the chest, strengthens the back, and gives tone to the muscles of the abdomen.

Boating should be recommended with certain precautions, and of course in properly selected cases to the subjects of lateral curvature of the spine, especially to those who exhibit the deformity in its early condition.

Such individuals should scull, not row. All those who take to boating should first learn to swim. Boys may begin to learn to row at six and girls at eight. It is a matter of the utmost importance that the learner be well taught.

It is well to begin in a light half-outrigged boat which will seat two, the

teacher and the pupil. The water should be smooth. The pupil should begin by pulling one scull only, rowing for equal periods upon the right and the left side. He will in this way learn the rough details of the stroke and the rhythm of the movement. He should from the first be made to keep time.

The exercise with one scull should be brief, and the sooner the pupil takes to both sculls the better. There is usually much difficulty with the left hand.

As soon as the pupil can scull moderately well he should row behind a good oarsman, and in this way he will pick up the swing of the movement and the proper points of the stroke.

Sea Rowing is inferior to river rowing as an exercise: the boat is heavy, the gunwale is high out of the water, the stroke is short, and the movement is not susceptible of the finish possible in a river boat.

Those who have rowed much on the sea will probably never row well on the river. The exercise involves more muscular exertion, which is, however, of a rougher, more clumsy and unfinished kind. To row a sea boat the individual must be strong. Sea rowing is not well adapted for children or for those who are muscularly feeble; and, while as an exercise it has admirable points, it should be borne in mind that on fresh water alone is the pursuit of boating capable of assuming its most perfect form.

Canoeing

For the purpose of the present paper canoes may be considered to belong to two classes—the Rob Roy canoe and the Canadian.

In the former the canoeist sits amidships with his lower limbs extended straight upon the floor of the craft. The paddle is of considerable length, and has a blade at either end. The canoeist holds it about breast high, and drives first one blade through the water and then the other. His back is supported by a rest.

In this form of canoeing the muscular exertion involved is limited to the muscles of the arms and shoulders, including the pectorals, trapezius, serratus magnus, and latissimus dorsi. The muscles of the neck and upper part of the back are concerned, but the body below the thorax is practically motionless. The exercise, therefore, is one of limited muscular applicability.

The exercise is good for those who wish to develop the arms or who from some deformity or defect are unable to use the lower limbs. It is not an exercise to be recommended to those who aim at developing the whole muscular system or who are the subjects of any spinal weakness.

In the Canadian canoe as adapted for use in England the canoeist sits at the extreme stern, either on the floor or upon a seat nearly flush with the gunwale, and with his feet on a stretcher. He has a short paddle with a single blade. He paddles upon one side of the craft only and steers by manipulating the blade at the completion of each stroke. In all but the smallest form of Canadian canoe a second seat is provided close to the prow for a second paddle. The fore paddle may be shorter, and is worked at a diminished advantage, and the steering of the craft must still remain with the paddle in the stern.

The Canadian canoe involves a much more complete form of exercise than does the Rob Roy canoe. The canoeist has no support for his back. He must keep himself erect by muscular effort. In effecting the stroke he employs, not only the muscles of the upper limb, but also the muscles of the trunk. The whole body undergoes some rotation in the vertical axis at each stroke. After long paddling, a sense of exhaustion is felt in the back and

about the loins, but not in the arms. The canoeist has also to balance himself, and as the Canadian canoe is carvel-built and keelless this involves some extra muscular expenditure. The after paddler can make considerable use of his legs, moreover; a help which is, to a great extent, denied to the paddler in the bow of the canoe. The canoeist should change his side from time to time—in other words, should not paddle for too long a time at a stretch upon one side. Paddling upon one side tends to produce much lateral bending of the vertebral column.

This exercise is not well adapted for the weakly, nor for those who have weak backs and a disposition to lateral curvature. For the robust it is admirable, and forms a very pleasant variation to rowing or sculling.

A voyage in a canoe usually involves exercise of the most varied kind: there are hard paddling against a stream, nervous steering down a rapid, the dragging of the craft over shallows and past milldams, and the very arduous task of making a way through thick rushes and weeds.

Cycling

The history of athletic sports provides probably no more remarkable feature than is afforded by the introduction and development of cycling. Twenty years ago the bicycle was unknown in this country. Even fifteen years ago riders upon bicycles were regarded as little other than acrobats and mountebanks. Within so short a period this form of athletic exercise has developed with almost incredible rapidity and with phenomenal vigour. Cyclists are now to be counted in tens of thousands, the sport has been taken up by individuals of all ages and in all stations of life, and has been enthusiastically patronised by women as well as by men.

The history of cycling is very admirably given by Mr. G. Lacy Hillier—himself a well-known rider—in the Badminton volume on 'Cycling.'

The general features of the cycles now in use must be familiar enough. There are two forms of bicycle, the 'Ordinary' and the 'Safety.' The Ordinary represents the earlier pattern. In this machine the wheel is driven by the direct action of the pedals. The size of the wheel depends upon the height or 'the reach' of the individual rider. A diameter of 50 inches will represent an average size. With this wheel the rider steers, and upon it he balances himself. In propelling this machine there is no waste of muscular force. The rider is placed directly 'over his work,' or, as it would be expressed with reference to other exercises, 'close to his work.' No power is lost upon cog wheels and chains, and the weight of the body can be admirably utilised in aiding progression.

The Safety bicycle represents the machine of the immediate future. The varieties of this cycle are legion, but the form most commonly used is founded upon what is known as 'the Rover' pattern.

The Safety bicycle is represented by a machine with the following characters. The two wheels are comparatively small, and are either of equal size or are nearly so. The diameter of each will be about 28 or 30 inches. The front wheel is the steering wheel, and with it the handles are connected; its movement, so far as the act of steering is concerned, is effected through a nearly horizontal joint, 'the head.' The hinder wheel is the driving wheel. It is not propelled by the direct action of the pedals. The pedals act upon a small cogged or toothed wheel carrying a chain, and through this chain the movement is communicated to the rear wheel. The rider sits directly over the chain wheel to which the pedals and their cranks are attached, and is therefore placed between the two running wheels of the

bicycle. The machine is said to be 'geared.' If the two pulley wheels with which the chain is connected are of equal size the machine is said to be 'level geared.' In such case one complete revolution of the pedal involves one complete revolution of the driving wheel. If the pulley wheels with which the chain is connected are of unequal size, and if the wheel connected with the pedal is the larger, the machine is said to be 'geared up.' In such case the pedal revolutions are fewer than the revolutions of the driving wheel. The Safety bicycle is usually 'geared up to 54;' that is to say, the relation between the wheel moving the chain and the wheel moved by it is such that the driving wheel, which has an actual diameter of 28 inches, revolves at each complete turn of the pedal through a range of movement equal to that made by one complete revolution of a wheel with a diameter of 54 inches.

Some tricycles are 'geared down,' by which term is implied the fact that the hinder of the two pulley wheels is the smaller, and therefore more than one revolution of the pedal is required to produce one revolution of the driving wheel.

In this question of gearing it must be remembered that one factor of the equation, viz. the strength of the rider, is a fixed quantity, and that either speed or power must be sacrificed when the other conditions of the problem are varied. If the machine be geared up, the rider can make fewer revolutions of the pedal than would be required if the gearing were level, but he must employ more force. On the other hand, if the machine be geared down an increased number of movements of the foot is required; but the amount of force involved is much less. A young man of light weight or an individual of feeble muscular power may prefer to use his legs with greater activity provided he can employ a lesser degree of muscular effort. Such an individual may prefer a cycle geared low. A man of more advanced years, of more than average weight, and of considerable muscular strength, would probably be glad to expend an undue amount of force on each stroke of the foot rather than to feel the necessity of moving his pedals rapidly. Such a rider would select a machine with a higher gearing.

While a roadster Safety will usually be geared to 54, a racer Safety of the same type may be geared to 63.

The Humber Roadster tricycle ('gents' light cripper') is geared to 57 in the maker's catalogue, the ladies' tricycle of the same pattern to 54, the corresponding racer cripper to 63.

The weight of a racing Safety may be reduced to 20 lb. complete. The weight of a racing tricycle (Humber Cripper) is given as 30 lb. A roadster Safety weighs from about 36 to 42 lb. A Roadster tricycle may scale from 45 to 56 lb.

The tricycle is well represented by the excellent machine known as the Humber Cripper. In this tricycle the front or steering wheel has a diameter of 24 in., the two driving wheels of 30 in. A single chain is employed. The saddle is placed well over the pedals, and the machine in all general features is based upon the mechanical lines of a Safety bicycle. The introduction of the ingenious ball-bearing joint to cycles of all kinds has reduced the amount of friction in running to a minimum.

The Safety bicycle if taken against any obstacle sufficient to stop the front wheel merely falls over on its side. The rider's feet are so close to the ground that it needs no very great inclination of the machine to enable him to bring one foot to the ground, and so prevent a fall.

The term 'Safety' is well merited. An accident, when it occurs, is probably the fault of the rider alone, and is inexcusable. There are many

who have ridden these machines for years over some thousands of miles of road, and who have yet never met with what may be termed an accident, or even a nasty fall.

One disadvantage which has been urged against all cycles is that of vibration. There is no doubt that long-continued vibration communicated to the body is injurious. It is unpleasant, it induces fatigue, and leads to earlier exhaustion of the muscles.

The effects of vibration are less felt in the young, and upon the bodies of lads under eighteen, who still possess many epiphyseal cartilages, a long-continued vibration may tell but little. But in older individuals, in those whose bodies have become more rigid in the process of development, and especially in persons with a sensitive nervous system, vibration has certainly an unfavourable effect. They return from a long ride over rough roads with an undue sense of fatigue—they feel 'shaken,' the back aches, the arm muscles are a little tremulous, and there often follow a headache and a sleepless night.

Vibration has been to a large extent overcome by the use of 'cushion' or 'pneumatic' tyres, or by means of a suspending spring, such as has been introduced, with the greatest success, in what is known as the 'Whippet' bicycle. The Whippet machine may be said to bear the same relation to the usual Safety bicycle which a cart with springs bears to one without springs.

The following records will give an idea of the possible speed which can be attained on a cycle:—

—	Bicycle	Tricycle
	h. m. s.	h. m. s.
Half-mile	1 8	1 17
One mile	2 20	2 37
Three miles	7 40	8 6
Ten miles	26 40	28 13
Twenty miles	55 0	56 40
Fifty miles	2 25 26	2 38 44
Hundred miles	5 50 5	6 9 26

Cycling as an Exercise

Bicycling.—A ride upon a bicycle involves not only an admirable muscular exercise, but it involves of necessity exertion in the open air. The exercise is continuous and not intermittent; it can be regulated to any degree, and can be indulged in equally by the athlete and the weakling.

He who owns a bicycle has at his command one of the most admirable and certainly one of the least expensive means of travelling. He is dependent solely upon himself, and can without difficulty travel fifty miles a day. No horse could compete in endurance and in long distances with the bicycle rider.

Cycling has undoubtedly done more than has any other form of physical exercise to improve the bodily condition of the city clerk and the shop assistant. The lad who is pent up in a close office all day has now no difficulty in finding a means for well occupying the summer evening or the few hours at his disposal before the work of the day begins. He has merely to mount his bicycle and in an hour he is ten miles away from the din of city life, and is breathing a clearer and brisker air. He who is an early riser can in the summer months well manage a twenty-mile ride before breakfast.

Unlike the player of cricket and football or the rowing man, the cyclist is dependent upon no one but himself. His means of exercise is always at hand,

and he can occupy a spare half-hour or the entire afternoon with the same amount of preparation.

The specific features of the exercise of bicycling may best be reviewed by discussing the objections which have been urged against the sport.

1. It is said to be dangerous. This objection without doubt applied to the high-wheel bicycle, but it can scarcely be said to be just as regards the more modern machine—the Safety. The rider rides with his feet but a few inches from the ground. If he is falling he has simply to step off. The machine cannot turn 'head over heels,' it can merely fall upon its side. The brakes now applied to these machines are so strong that they can bring the bicycle to a standstill in a moment.

The most serious accidents have occurred in riding through crowded streets, and unless a rider is perfect at his work, and is as quick as a hare, he is merely foolhardy if he attempts to ride through a very busy thoroughfare.

Bicycling may be said to be less dangerous than riding on horseback, especially when the distances travelled are taken into account, and to be certainly less risky than skating.

2. A second objection to the bicycle is that it is a very partial exercise, and that it involves the use of the muscles of the legs only. It may be said at once that the first difficulty of bicycle riding is not the propelling of the machine, but the maintenance of a proper balance. The learner after his half-hour exercise will not complain of aching in his legs, but of aching in his arms and, to a lesser degree, in his back. The beginner is apt to believe that the whole strain of the exercise comes upon the forearms. In other words, the grip of the steering wheel and the easy, immediate, and complete control of that part of the machine are the first principles in bicycle riding. To preserve the upright position many muscular movements are required, and in these practically all the muscles of the trunk are concerned.

In course of time balancing becomes not only easy but quite automatic; and while it is true that the upright posture is finally retained with a very modified amount of muscular exertion, still an extensive series of muscles are involved even if the power exerted be slight.

To sit upright for some hours without any support for the back is not a quite insignificant exercise, and after a long ride the bicyclist finds that he has been doing more with his back than he thought.

So far as the movements of the legs are concerned, an opinion of bicycling as a muscular exercise should not be formed by observing the riders one often sees in the streets of a great city on Sunday or on the suburban roads on a Bank holiday.

The ill-taught or inexperienced rider rides from his hips; he moves his lower limbs like pistons; his action is extreme; his ankle is fixed; his foot and leg move as one.

Pedalling is, to a great extent, a matter of the ankle-joint. The more the ankle-joint is employed the more is muscular power economised, and the more graceful is the rider's movement.

While bicycling does certainly involve in the main the muscles of the lower extremities, it at the same time gives excellent employment to the muscles of the upper limb (especially of the forearm) and to the muscles of the trunk.

Cycling does not tend to develop the chest or exercise the great muscles passing from the trunk to the upper limb, and herein lies the defect of the sport as an exercise. It cannot be recommended as a predominating mode of exercise to a tall, lanky lad with a narrow chest and a stooping back. Such an individual should take to rowing and leave the wheel alone.

3. In the third place it is said that bicycle riding induces a very pernicious posture of the body—a posture which has been well caricatured by Du Maurier in the pages of 'Punch.' The posture complained of can be seen any day among those who hire a bicycle now and then for an hour and tear wildly through the streets thereon. The rider is leaning so far forwards as to have his body nearly horizontal. His back is bowed and arched, his elbows stick out like the limbs of a startled cat, his chest is almost upon the handle bar, and his chin is thrust well ahead.

This attitude is, to some extent, a necessity upon the racing track, and there is no doubt that it is practically essential in riding at the highest possible speed.

For riding upon the road it is ridiculous and as out of place as the posture of a jockey at the finish of a horserace would be in an individual taking a canter in Rotten Row.

This absurd attitude when assumed by riders on the road may be put down in part to sheer ignorance, in part to bad teaching, and in part to a foolish imitation of the racing man. It is unnecessary, inelegant, and distinctly injurious.

The rider should sit quite upright, with his back straight and with the upper part of the body as still as possible. The head should be erect, the shoulders well thrown back, and the elbows at the sides. He should sit, moreover, well to the back of his saddle, and, as one writer expresses it, 'push out in front, using the saddle to push from.' The handles of the machines are now made so as to render a perfectly erect position possible; and in ordering a machine it is important that this matter of the handles should be attended to.

There is no doubt that some riders who have been utterly careless of their attitude have to thank the bicycle for rounded shoulders and a stooping back.

4. It is said that in cycling injurious pressure is brought to bear upon the perinæum, and that perinæal abscess, urinary fistula, and other troubles have resulted therefrom. The writer has not been able to find any evidence to support this assertion.

It is possible that cycling may lead to mischief if practised by a patient with an inflamed urethra; it is conceivable that it may act injuriously in the subjects of urethral stricture and enlarged prostate. For even this last-named possibility there is very little scientific support. Among tricycle riders the writer is acquainted with more than one subject of prostatic, hypertrophy, and by such individuals he has been assured that cycling causes no aggravation of such symptoms as they present. In the advanced stages of prostatic trouble in elderly men, when vesical symptoms are present, cycling could scarcely be practised.

In perfectly healthy individuals it may be stated that cycling does not produce an injurious degree of pressure upon the perinæum.

In the modern saddle a suspended slip of leather is the only part which comes in actual contact with the perinæum. No metal-work can cause direct pressure upon that part.

Any discomfort about the perinæum in riding is probably due either to a form of saddle ill-adapted to the individual rider, or to a bad attitude assumed in riding.

The habit of stooping forwards, which has been already condemned, brings the perinæum unduly upon the saddle, and for this reason, if for no other, the attitude is to be strongly opposed.

In riding, the weight of the body rests upon the tuberosities of the ischia. These points alone should bear the pressure.

Many bicyclists wear suspensory bandages on the ground that the testes are occasionally pressed between the body and the saddle. Such a precaution is unnecessary if the rider will make up his mind to sit his machine properly.

It is needless to say that long-continued pressure upon the tuber ischii may lead to some pain along the long scrotal nerve and may induce an enlargement of the bursa over that process of bone.

The circumstance is, however, very rare, and is no more likely to occur after cycling than it is after daily riding in a third-class railway carriage.

5. Cycling is accused of producing varicose veins in the leg, and hernia. The case of the first-named affection is considered elsewhere, and need not be again dealt with.

With regard to hernia there is little to add to what has been already said, except to point out one fact. It is true that in easy riding the abdominal muscles are but little used, and that, therefore, little pressure is brought to bear upon the abdominal viscera.

Indeed, in ordinary riding the abdominal muscles have singulary little to do. This circumstance may appear to render bicycling a suitable exercise for those who are disposed to hernia. It must, however, be noted, on the other side, that the attitude of the rider tends to so relax the tissues about the hernial orifices as to render the circumstances favourable for the descent of a hernia. When the rider 'puts on pace' in racing or in avoiding an obstacle he leans forwards, throws his abdominal muscles into action, and places himself in a condition certainly favourable for the formation of a rupture. In 'mounting' also a sudden and pronounced contraction of the belly muscles is called for, and that, too, while the individual's body is flexed.

It may be said, therefore, that bicycle riding should be avoided by those who have weak inguinal regions or a disposition to hernia, and that it should not be practised by the actually ruptured.

Bicycling is well suited for the young, nimble, and active; it is, however, not ill-adapted to the middle-aged and to those who have lost the elasticity of youth. A man of forty, weighing 13 or even 14 stone, may take to bicycling as an exercise, may attain considerable proficiency as a rider, and may derive unmixed benefit from the pursuit. He needs be nimble enough to mount and to dismount quickly, but this involves little more agility than is required to enter or to leave an omnibus while in motion. Bicycling is not adapted for men past middle life, and there are very few riders who may be classed as old men.

The exercise is admirable for all who require development in the lower extremities and who complain of being 'weak in the loins.' Those who are disposed to phthisis or who desire to develop their lung capacity should take up some other exercise than bicycling. It is not perhaps quite the exercise for the timid and nervous, and it should not be adopted by the subjects of urethral or prostatic disease, of hernia, of varicose veins, or of varicocele.

The exercise appears to have a very beneficial effect in relieving chronic constipation, and is adopted with advantage by those who are the subjects of dyspepsia, hæmorrhoids, and functional disorders of the liver.

As in other forms of exercise, racing and the breaking of records should be left to the young, well-trained, strong, and athletic, and the acquiring of tricks in riding to the acrobat, who has to live by his eccentricities. The ordinary rider when touring should satisfy himself with a pace of not more than ten miles an hour, and a distance not exceeding fifty miles in the day.

The bicyclist should be well equipped, should wear well-cut or, better still, well-woven breeches, should be clad entirely in wool, and should burden himself with as little luggage as possible. He should avoid tight-fitting shoes, stiff collars, braided uniforms, gauntlets, rubber-soled shoes, and waterproof suits. The only waterproof worn should take the form of a loose cape. The best shoes are thin leather walking shoes.

Tricycling.—In tricycling the muscles of the lower extremities are almost the only ones involved. No balance has to be maintained, and the steering is accomplished with a very small amount of muscular exertion. The rider has to maintain the body erect, and must thus employ the muscles of the trunk. As an exercise, tricycling is undoubtedly inferior to bicycling. The machine is, moreover, comparatively large and cumbrous, and in a small London house is perhaps with difficulty disposed of. It cannot be so well conveyed from place to place, and when on a tour the rider must always seek a shelter for his machine. The small size of the bicycle and the convenient manner in which it can be disposed of are among its greatest advantages.

The tricycle rider must keep to main or principal roads. The bicyclist can take advantage of a footpath. The machine makes three tracks, and upon an uneven or frozen road with sharp ruts the tricycle has very decided disadvantages over the bicycle.

While in touring the bicyclist can make ten miles an hour, the tricycle rider will have to content himself with eight. On the other hand, the advantages of the tricycle are the following. The machine is very easy to ride, and can be ridden at once and without any teaching. No balancing is required. The machine can be driven with less muscular exertion, and by altering the gearing a machine can be adapted to almost every grade of muscular capacity. The tricycle can be ridden by the old, the nervous, the moderately feeble, the lame. It can be ridden by ladies and young girls. At the same time, with an athletic rider a great speed can be attained on the machine and enormous distances covered.

Three great and very decided advantages of the tricycle are these: the rider can stop the machine, and can rest and enjoy the scenery, without dismounting; he can ride without taking very minute note of the road; he can carry a considerable quantity of luggage.

Tricycling is a most admirable exercise for those past middle life. They can take their exercise without fear and without trouble, and can moderate their exertions to any degree. It can be made a violent exercise or a very gentle one. It throws no great strain upon the heart or lungs. It appears to have a good effect upon dyspeptics and the subjects of chronic constipation. It can be indulged in within limits by the subjects of hernia. It involves all the advantages attending exercise in the open.

Cycling for Ladies and Girls

Tricycling is extensively and enthusiastically adopted by many ladies and young girls. Many have attained considerable proficiency at the sport. The luxury of a tandem ride appears to be keenly appreciated: the freedom the lady tricyclist enjoys, and the wide tracks of country she can cover in company with her brother, husband, or other friend are strong attractions for the vigorously inclined.

It is doubtful if tricycling can be declared to be a good or suitable exercise for young women and young girls.

It is not a severe exercise, it is true; and, indeed, the amount of muscular

exertion demanded can be very precisely regulated. Many ladies are emphatic in their advocacy of the claims of tricycling to be considered a very suitable, very beneficial, and quite harmless exercise for females.

It must be remembered, however, that what applies to one woman may not apply to another, and that arguments applicable to the middle-aged may not be equally suited to the young.

The precise evidence which is required to decide the question of the value of tricycling for women and girls is a little difficult to obtain and to formulate.

These points may be drawn attention to.

It is a question whether an exercise involving extensive use of the lower limbs and of the muscles about the pelvis is an unmixed good during the years of active uterine life.

During the menstrual period it may be assumed that the exercise would, for many reasons, be regarded as most undesirable; and there may possibly be some truth in the loose assertion that menstrual irregularities have been developed by tricycling. There is a real difficulty in the matter of the saddle. The modern ladies' saddle is a great improvement upon the older pattern, but the writer knows of no saddle which can be assumed to entirely do away with the possibility of pressure upon the pudendum.

Individuals have complained of much chafing in the pudendal region as a result of riding, and, without entering into further details, the question may be asked whether in young girls or in young women an exercise is good which may involve considerable pressure and friction in the pudendal region. The very detailed objections which have been allowed to apply to the use of treadle sewing machines by factory girls would appear to apply to the riding of a tricycle.

My personal opinion would take the form of suggesting that there are better exercises for the gentler sex than tricycling provides, that the exercise should not be undertaken by young girls and young women, but that it may be open to those who are married or middle-aged. I am aware of one or two instances in which ladies have abandoned tricycling after a few months' enthusiastic pursuit of the exercise without affording a more definite excuse than that 'it did not agree with them.' That tricycling is not the exercise best suited for a girl about puberty or a young unmarried woman I am convinced, and one cannot help noticing that the most enthusiastic, most successful, and most persistent lady riders are no longer young.

Bicycle riding for ladies and girls may be condemned for the same reasons which have been mentioned in connection with tricycling. Very ingenious Safety Bicycles for ladies have been designed, but it is evident that—with the present shape of saddle at least—they cannot be ridden without producing pressure and friction in the pudendal region. The mounting and dismounting is difficult: although it can be performed with perfect decency, the learning to ride involves greater pains, and the dress distinctly adds to whatever dangers may attend the machine.

There are many very admirable, harmless, and delightful exercises open to the tender sex, but among these cycling, and more especially bicycling, need not be included.

Gymnastics and Calisthenics

These terms have been, and are, employed in so many senses that they scarcely admit of any precise definition, and certainly of no definition which would meet with general acceptance.

The term 'gymnastics' is usually considered to apply to a series of exercises of a somewhat severe or advanced character, and especially to such as involve the use of apparatus. The term 'calisthenics' is usually associated with a milder form of systematic exercises, with 'free movements,' with exercises which involve no apparatus, with the simpler forms of drilling, and the like. The definitions of the words given in the 'Century Dictionary' are convenient ones. '*Calisthenics*: The art or practice of exercising the muscles for the purpose of gaining health, strength, or grace of form and movement; a kind of light gymnastics.' '*Gymnastics*: The art of performing athletic exercises.'

The first expression which presents itself in the consideration of gymnastic exercises or the teaching of calisthenics is the unfortunate term 'system.' The question asked of any instructor is 'what system does he teach?' and of any scheme of exercises, 'what system does it follow?' Considerable discussions have ensued upon the question as to which system of gymnastics is the best; and while at one centre of physical education faith is fixed upon one system, an opposite belief holds sway at another.

When the details of opposed systems are considered, and the claims of rival schools are weighed, no little confusion arises. The impartial observer feels that he must seek for some great fundamental characteristics whereby to separate one method from another. He finds that original systems have been modified, reconstructed, added to, and even blended with methods from other sources. He observes that the conception one instructor of gymnastics has formed of a system of training differs materially from the interpretation another teacher has adopted of the very same system. Several of the more modern works upon gymnastics form a mere olla podrida, a mixture of this system and of that, with modifications introduced by the author and such emendations as obscure all means of classification.

I have myself witnessed a 'display' advertised as a demonstration of the Swedish system of gymnastics, in which musical drill, the use of bar-bells and dumb-bells, were the main features, and in which none of the familiar characteristics of the Swedish system were notable.

As a matter of fact, the terms 'Swedish system,' 'Swedish gymnastics,' and 'Ling's method' are used in so indiscriminate a manner, that the expressions have in the mouths of many become to be synonymous with any form of free movements or any species of gymnastic training which is not violent or which does not involve fixed apparatus.

One soon has to conclude that no one system is *per se* complete and all-sufficient, that no one can lay claim to international adoption, that evil may result from a blind adhesion to one particular method, and that considerable allowance has to be made for nationality, physical condition, and physical tastes.

While this is true it must also be allowed that if a certain system be advocated and professed it should be maintained in its entirety so long as its distinctive title is adhered to and employed.

So far as the present purpose of this article is concerned, it may be said that there are three methods of gymnastic exercise which for purposes of convenience may be here set forth. It must not for a moment be supposed that such a classification is in any way complete, nor is it historically precise, nor perhaps even just. The systems alluded to are—1, the English; 2, the German; and 3, the Swedish.

1. By the *English system* is understood a method of physical training by means of athletic exercises and outdoor sports. This system is considered to include marching, running, both long distance running and sprint running, leaping, swimming, &c., trials of strength and endurance, and the usual outdoor sports, such as cricket, football, and rowing.

This is the sense in which most foreign writers describe the English system. The definition is not very liberal, but it is very convenient. It is true of physical training in England many years ago, but of course does not profess to represent such training as is at present carried out.

It is needless to criticise what is termed the English system. The value of athletic sports and outdoor games is recognised and is appreciated in no country so keenly as in England.

As a method of training, it is obviously crude, unscientific, incomplete, and of restricted application. It is a pleasant training for lusty boys and vigorous men, but it is perfectly clear that it can lay no claim to be considered as a precise and orthodox system.

2. The *German system* may be spoken of as being assimilative. The German writers and teachers have adopted and embodied whatever they found good in the practices of other peoples in the matter of physical education. No system is more liberal, more extensive, more catholic. As Mr. Metzner well says in his account of the German system of gymnastics (Physical Training Conference, Boston, 1889), 'the German system does not claim to have any special exercise of its own, or to be the sole proprietor of any that no other system may also produce.' The system has been slowly built up during nearly a century, and has shown as a main characteristic the power of intelligent assimilation and the ready appreciation and development of what has appeared good in physical training.

The German system embraces all the different branches of gymnastics, free movements, mass exercises in every form, with wands, dumb-bells, flags, bar-bells, &c., figure marching, trot marching, the use of a most varied and extensive series of fixed apparatus, the use of clubs and all forms of hand apparatus, and the encouragement of such exercises as come under the heading of outdoor sports.

It aims at general physical culture and does not encourage the development of especial powers or especial abilities; it encourages exercises in classes (mass exercises) and endeavours to infuse interest and amusement in its instructions; it aims at being complete and of being capable of adaptation by individuals of all ages and of very varied physical ability; it encourages a gradual and progressive form of instruction, the pupil commencing with the simplest exercises and proceeding with the more difficult and arduous only when the more rudimentary have been fully mastered.

A description of the exercises carried out under the German system would require a treatise of considerable length. (*a*) The *free exercises* imply various movements of the limbs and trunk carried out without apparatus. They include manifold movements of the arms and legs, bending and rotating of the body in various directions, and the assuming of a number of attitudes and postures.

By these free movements it is considered that every muscle is exercised; the exercises are simple, gentle, and are especially adapted for children, although they should form the preliminary course in any scheme of physical training. They are repeated a great number of times and are effected symmetrically so that each side of the body may be equally developed. They are so arranged as to be progressive, and every attempt should be made to render them complete. These exercises are obviously best conducted in classes, and many are very conveniently carried out to music, as the German system allows. They are popular and interesting. They tend not only to develop the muscles but also to quicken attention, to encourage rapid, precise, and well co-ordinated movements, and to bring about the mental alertness and the physical smartness which are elicited by any well-conducted drill. They

tend to give grace and ease and freedom to the movements and to favour a good carriage.

No system of physical education is complete which is not founded upon a sound grounding in free exercises.

It is only fair to state that some of the best of the free movements carried out in the German system have been derived from the Swedish schools. The exercises are perhaps, on the whole, more interesting and more picturesque than those adopted by the Swedish system. They are, however, less precise and less complete and less elaborately systematised as a part of a progressive system of education. Not a few of these German free exercises have little educational purpose, and appear to be adopted more for effect and to meet the requirements of a public display. Some recent modifications and additions have little claim to serious attention, and do not elicit the best possible employment of the pupil's time. Compared with the Swedish exercises, however, they are, on the whole, more popular with children, and are certainly more picturesque.

(*b*) Another series of exercises involve the use of very light *hand apparatus*, such as bar-bells, wooden dumb-bells, flags, hoops, &c. These exercises, although they concern to a great extent the upper part of the trunk and the upper limbs, involve also the development of the other muscles of the body. The weight of the apparatus used is but a slight element in the exercises, which are nearly of the same character as those just described. The apparatus gives precision to the movements, makes the exercises more interesting and more easily carried out, and renders the instructor's work somewhat less difficult. These exercises are adapted for elder children and form a peculiarly valuable element in education. They represent an advancement upon the free movements, and in a systematic and progressive plan of instruction would naturally follow upon those exercises. These exercises with apparatus may also be carried out to music.

(*c*) Although *drilling* does not form a very conspicuous element in the German system, the subject may be conveniently introduced here, especially as the modern gymnastic drill is largely a German production. A certain amount of drilling is of value, and forms an efficient means of cultivating a good carriage and an easy and free mode of walking and marching. Military drill is a little tedious and formal and, to a considerable extent, purposeless, so far as a full physical education is concerned. It tends to sharpen the wits of dull lads and to encourage precise and active movements. It is, however, uninteresting to the pupil, and does not afford in any way a complete or satisfactory method of employing the muscles. In the physical training of children it may well be replaced by more valuable exercises.

The musical drill of more modern times is very different from the drill-sergeant's work. Musical drill appears to have been introduced from America, and it now forms a conspicuous feature in most training schools. It consists of marching or running in such a manner as to describe a variety of figures, and always to music.

Under this heading come the many forms of the musical running or marching maze, which include marching in two or four circles, or in reverse circles, or in parallel lines, or in what is known as the serpentine course. This drill is only possible with a comparatively large class. It is very popular with children and with lads and elder girls. It forms an excellent relaxation from the more formal exercises and represents running with a purpose. Many admirable books have appeared on the subject. The three forms of exercise just described are especially well adapted for children and for instruction in schools. They serve to form the basis of a very sound and perfect physical drill.

If the work of a school could be interrupted for thirty minutes in the middle of the morning in order that the children might go through some few dumb-bell or bar-bell exercises in fresher air, and then finish up with the running maze to music, something would be done towards securing a reasonable development of the body. All that is required is a competent teacher, plenty of floor or ground space, some very simple apparatus, and equally simple music.

(*d*) The use of *gymnastic apparatus* is considered in a subsequent section. In the employment of apparatus and in the invention and elaboration of gymnastic appliances of various kinds the German schools have been very active. Indeed, the use of apparatus is so prominent in the system that it has been often improperly considered to represent its principal feature.

3. The *Swedish system*, or the system introduced by Ling, has attracted very considerable attention, and has certainly been the means of effecting not only a remarkable improvement in physical education, but a change which may be spoken of as little less than a revolution. It may be that the whole method is not original, and that some of its features have been anticipated, but as a system it has been enthusiastically accepted, and certainly met a want which had been felt in physical education.

There was a time in this country when in the matter of physical education there was little between somewhat violent outdoor sports and certain acrobatic feats in the gymnasium on the one hand and the dreary instruction of the drill-sergeant on the other. The young girls of that period had also, it must be allowed, the services of the so-called professor of deportment, but of the value of his instruction it is difficult to speak. Physical training in those days was for the strong. It encouraged specialisation; it did not concern itself with a systematic and progressive development of the human body.

The Swedish system of physical training includes a very extensive series of free movements, a series of exercises involving marching, leaping, running and climbing, and certain carefully graduated exercises on the boom, rib-stool, and window ladder. The free movements are admirable, and for them these advantages can be claimed. They have been carefully worked out: each series of movements are definite and precise, and are intended to develop a special series of muscles; the exercises are systematic and progressive, and form in their entirety a complete and simple system of physical training.

The movements are not designed with a view to effect or display, but simply to carry out the scheme of muscular training. They are designed with care, and each accomplishes a specific object. The exercises begin with the very simplest and gradually become stronger and more complicated.

The use of hand apparatus is only sanctioned after a complete mastery of the free movements have been attained, and then only to add some intensity to those movements.

The fixed apparatus mostly employed by teachers of the Swedish system are the boom, the rib-stool, and the window ladder. The latter forms an excellent exercise for children and affords them no little amusement. The method prepares the way for so-called æsthetical gymnastics, for fencing, military drill, and other forms of applied gymnastics.

All the movements of the drill are applied to words of command, and the pupil gains all those advantages, mental and otherwise, which attend the teaching of exercises by the drill method, i.e. by word of command rather than by imitation or by committing the movements to memory.

The Swedish system disapproves utterly of the use of music, and it is contended that the exercises cannot be adopted to one set rhythm.

Against the Swedish method it may be urged that the exercises are a little uninteresting to the pupils, that many of them appear ungainly and purposeless, and that the great advantage of a musical accompaniment is lost.

The chief movements may be classed under the following divisions:

(*a*) *Fundamental positions.*—These are intended to secure general attention and muscular control, and to establish the equilibrium and base of support before more difficult exercises are undertaken.

(*b*) *Arch flexions* comprise various forms of backward flexions of the trunk, and are intended to develop the dorsal muscles and those of the abdomen, and to expand the lower part of the chest.

(*c*) *Heaving movements.*—These comprise forms of self-suspension by means of the arms on a horizontal bar or other apparatus, and serve to expand the chest and to strengthen the muscles of the upper limb.

(*d*) *Balance movements.*—The positions are taken from a smaller area than that included within the feet in standing; the difficulty is increased by diminution of the area of support. The exercises develop the equipoise of the body and give grace to the carriage.

(*e*) *Shoulder-blade movements* are concerned mainly with the scapular muscles.

(*f*) *Abdominal movements* call into special action the muscles of the abdomen.

(*g*) *Lateral trunk movements.*—These include various forms of lateral flexion of the body, and of rotatory movements, and concern generally the muscles of the trunk.

(*h*) *Slow leg movements.*—They are to specially develop the individual muscles of the leg.

(*i*) *Jumping and vaulting*, and (*j*) respiratory exercises call for no explanation.

In the article on 'Physical Development,' in Keating's 'Cyclopædia of the Diseases of Children' (vol. iv. p. 303), will be found a brief but lucid exposition of the actual details of the Swedish drill, illustrated by numerous figures of the various positions.

An excellent 'Manual of Swedish Drill' has been produced by George Mélio (London, 1889). The reader may also consult a 'Manual of Free-standing Movements,' by Captain Haasum, of the Royal Gymnastic Institute, Stockholm (London, 1885). Both books are admirable. Mr. Mélio's various contributions to our knowledge of Swedish gymnastics have been very valuable, inasmuch as his early training was not carried out under the Swedish method.

The Swedish system of physical training originated with Ling, and has been considerably developed and extended by his pupils and followers.

Petter Henrik Ling was born at Ljunga, in Smaland, in 1766. His early life appears to have been absorbed by a struggle against poverty, and he passed through many vicissitudes. He seems to have been engaged in many pursuits and to have travelled in many countries. In 1800 he was studying gymnastics at Copenhagen, and in 1804 he was engaged as a fencing master at Lund. His system of physical training was elaborated after this date. The Royal Gymnastic Institute was founded at Stockholm in 1815 at his instigation, and remained under his supervision until his death in 1839.

Ling figured as a poet and a dramatist; he dabbled with the flimsier forms of metaphysics and held some crude conceptions of physiology. His education was scarcely such as to fit him for the position he ultimately held.

Ling held that life consisted of the blending together of three elements—the dynamic, the chemical, and the mechanical—and upon this belief his

'system' was founded. Many of his exercises were only suited to invalids, and he professed to have discovered the means of curing most diseases by physical movements. His exercises were indeed divided into scholastic, military, medical, and æsthetic gymnastics. He considered that every muscular movement had a special effect upon the general health, and held that passive movements had a definite value in promoting the development of the body.

It must be confessed that his system (excellent as some features of it undoubtedly are) was founded upon not a few extravagant theories and upon bases which were not always scientific or accurate.

The medical side of the system has been the means of fostering a form of quackery, and has led to the introduction of the 'remedial exercises' and 'movement cures' which have done so much to bring Swedish gymnastics into discredit in this country. Out of the complex, heterogeneous, and visionary material which makes up Ling's system, much that is really good and valuable has been extracted. This is represented by the excellent system of free movements already described and by many of the methods of treating diseases by exercise which have been heartily accepted and developed by the medical men of this and other countries. In Anna Arnin's 'Health Maps' (London, 1887) and in Schreiber's 'Manual of Treatment by Massage' (Edinburgh, 1887) will be found good accounts of the application of movements to the treatment of abnormal and diseased conditions.

In proposing a course of 'Swedish gymnastics' or in advocating 'Ling's system' it is desirable that a clear knowledge should be possessed of what is implied by these terms, and that encouragement be not offered to the 'remedial measures,' the 'movement cures,' and the quackery with which this otherwise excellent system is attended. Any instructor who describes himself as a 'medical gymnast' will probably not be sought for as a teacher.

Ling's system *in its entirety* could hardly be accepted at the present day. Such portion of the Swedish system as deals with the practical part of physical education pure and simple must, however, be accepted as of considerable worth.

Gymnastic Apparatus

Under this title will be considered the use of such apparatus as will be found in a well-equipped gymnasium. A good gymnasium should have ample space, good light, very free ventilation, the best possible apparatus, and a fully qualified instructor.

The fresher the air and (within limits) the cooler the room the better. A properly ventilated gymnasium has an unlimited supply of fresh air without draughts. If there be a time when plenty of oxygen is required it is when young persons are taking violent exercise. Many gymnasia are ill-lit, cramped, and very badly ventilated.

The majority of the exercises involved in the use of gymnastic apparatus involves considerable strength and much practice.

It is madness for a man out of training and unaccustomed to exercise to commence in a gymnasium the use of such apparatus as the horizontal bar or the vaulting horse. Many children, especially girls, have been seriously damaged by the violent exertions undertaken in improperly conducted gymnasia.

Such gymnasia have done a very great deal to bring physical training into discredit. A boy of about ten has joined a 'gymnastic class;' his physical condition has never been examined and his physical capacities never inquired into. He enters the gymnasium, and without any preliminary training

attempts the feats he sees other pupils performing without perhaps having received any definite instruction. The boy goes home dead-beat, feeble, and sick at heart at his ill-success and aching with his unwonted exertions. Next day he presents all the phenomena of extreme fatigue and perhaps the symptoms of muscular strain. I have known more than one instance in which a hernia made its appearance after a first attendance at a gymnasium.

The very greatest care should be exercised in the management of all children and young people sent to a gymnasium. Parents who take infinite pains to supervise the mental education of their children often take not the least trouble to ascertain the conditions under which their bodies are being trained. A lad comes home with a headache and with all the symptoms of exhaustion from the hour's drill, and is not allowed to attend again on the grounds that he is not 'strong enough for rough exercise.' A visit to the gymnasium may have shown that the headache was due to an ill-ventilated and over-heated room, and the exhaustion to totally unsuitable exercises.

It must be remembered that physical training requires discretion; that a great mass of pupils, even when of the same age and sex, cannot be all dealt with *en masse* by fixed rules. The exercises selected and the apparatus to be used must be determined, not by rule of thumb, but by the precise needs of each individual case. This observation will not apply to drilling and to simple mass exercises, but it applies in a very emphatic manner to apparatus.

A gymnasium is worse than useless without an efficient and careful instructor. Gymnastics cannot be self-taught. The process of training must be gradual, and so graduated as to meet the pupil's particular needs and particular state of development.

So-called exercise in a gymnasium without a teacher usually means purposeless romping. It may safely be said that the great majority of the accidents which occur in gymnasia occur during forbidden hours or when the pupil is attempting exercises by himself of which he has no precise knowledge.

Put an active boy in a gymnasium and pay no attention to his training, and he will assuredly begin to 'play the fool,' to 'skylark,' to develop uncouth modes of exercising his limbs, and in the end very probably do himself more or less material damage.

The pupil in a gymnasium must be content to begin at the beginning, must learn to be patient and to overcome failures, must be ready to believe that there are many exercises he can never perform, and that he is endeavouring to acquire health and strength, and not to qualify himself for the profession of an acrobat. Above all things, work in a gymnasium must be gradual, regular, and systematic.

A very lamentable spectacle is that afforded by a middle-aged man who feels he is becoming stout and who thinks he will 'take to gymnastics.' He attempts at once the exercises he sees his younger colleagues perform with such complete ease. If such a man escapes with no greater injury than is represented by being rendered breathless, by having several muscles sprained, and by being laughed at, he may consider himself fortunate.

In general terms it may be said that the gymnasium is not well suited for children, is best suited for lads and young men between the ages of seventeen and twenty-five, and is but indifferently adapted for men over thirty, unless they have kept up the physical acquirements of their youth by constant practice.

It is important also to bear in mind that gymnastic exercises with apparatus all tend to develop the upper limbs and the upper half of the trunk.

The gymnasium cannot provide the means for a complete physical education, and work in it should never so far absorb the time devoted to

physical training as to exclude recreation in the open air and outdoor games and exercises. Exercises with apparatus come at the end, and not at the beginning, of a course of physical training.

A very brief description of the commoner apparatus will now be given.

Dumb-bells.—These should be light and should be made of sycamore wood. The weight for boys should be 1 lb. each bell, 2 lb. for lads, and 3 lb. for adults. Heavy dumb-bells are to be condemned. The chief feature of proper dumb-bell exercises is the great frequency with which they are repeated and the length of time the movements are kept up. The weight of the bell is not a factor of any moment in the exercise, but the apparatus serves to give interest and precision to the movements carried out. Heavy dumb-bells involve considerable effort compressed into an inconsiderable time. Such bells are only of use to athletes who wish to specially develop their arms.

Dumb-bell exercises are admirable. They can be adapted for individuals of all ages and of all conditions of physical strength; they are well suited for class exercises; and a musical drill with light dumb-bells forms a pleasant feature in the training of boys and girls. Both bells should be used at the same time.

The exercises encourage a good carriage, rapid and precise movements, and the equal, symmetrical, and simultaneous use of the muscles upon both sides of the body.

These exercises tend to develop the chest and to exercise the muscles of the abdomen and back.

It is true the arms are conspicuously employed in dumb-bell movements, but if the drilling is efficient nearly all the muscles of the body are well, although not equally exercised, and especial employment can be given to the muscles of the back.

Bar-bells.—These are of ash. The shaft is five feet long (for adults) and three-quarters of an inch in diameter. The knob at each end is three inches in diameter.

The exercises carried out with bar-bells resemble those performed with dumb-bells. They have especial value in developing the muscles of the chest and of the abdomen. The muscles of the upper limbs are somewhat unduly exercised, and considerable work can be thrown upon the muscles of the back. This apparatus is excellent for the narrow-chested. It encourages symmetrical movements, a graceful carriage, and general lissomness of the body. Bar-bells are extensively used in the training of young girls.

By the use of double bar-bells a still more extensive use of the general muscular system is involved. In these exercises two bar-bells are held at either end by two pupils; in all movements the two pupils must act in concert. The exercises concern the whole of the muscles and afford excellent training in symmetrical, rapid, and precise movements.

Indian Clubs are made of pine wood, and are about 24 in. in length and some $3\frac{1}{2}$ in. in diameter at the thick end. The exercises are only suited for adults and for muscular persons. They encourage a firm and upright attitude, and develop principally the upper part of the trunk and the upper limbs.

Many of the movements are very elaborate and require great nicety of execution.

Parallel Bars should be about 9 ft. long, 20 in. apart, and about 4 ft. from the ground. Every instructor in gymnastics recognises that the parallel bars form one of the most useful apparatus in the gymnasium. 'The exercises,' writes Maclaren, 'are not only numerous but varied, interesting, and in themselves pleasurable, capable of much artistic effect, and requiring equally muscular power and dexterity of action in the upper limb.'

The usual exercises are progressive and none are violent. The apparatus is suited for properly trained pupils of any age after twelve or fourteen, and within limits for both sexes, provided that the muscular development of the learner is efficient. The exercises improve the grasp, develop the muscles of the upper limb, and especially the muscles passing between the upper limb and the trunk. They are well adapted for individuals with slight arms, with narrow and sloping shoulders, and with contracted chests. Excessive use of the bars tends, however, to develop to excess the posterior scapular muscles. The muscles of the abdomen are employed, but comparatively little use is made of the lower extremities.

The Horizontal Bar is about six feet long, has a diameter of $1\frac{5}{8}$ in., and is raised from three to seven feet from the ground. This valuable apparatus is adapted for pupils of almost any age above ten or twelve. The exercises are varied and progressive, and can be made to suit various degrees of muscular development.

The simpler exercises develop the muscles of the upper limbs and of the upper part of the trunk; the more advanced call into play the muscles of the back and of the abdomen and to a less extent the muscles of the lower limbs. The apparatus if used to too great an extent tends to develop the upper limb muscles to a disproportionate extent.

The simpler exercises are adapted under careful restriction for girls with weak spines, and for those with small scapular muscles and slender shoulders.

The more elaborate exercises require considerable strength and agility, and are only suited for the athletic and very muscular.

In certain of the primary exercises the abdominal muscles are especially employed.

The Trapeze is made of hickory or ash, is about 20 in. in length and some $\frac{3}{4}$ in. in diameter. The height at which it is suspended from the ground, and the length of the ropes, must depend upon the capacity and age of the learner.

The exercises are very similar to those of the horizontal bar, but as the pupil can swing at the time of practising this apparatus is very popular.

It mainly brings into play the muscles of the upper limbs and those passing between the trunk and that member. It is of service in cases of feeble back and commencing lateral curvature, and can be made admirable use of in developing especially the muscles of the abdomen.

A mattress must always be placed beneath the low trapeze and a net beneath the higher apparatus. Great care must be taken in carrying out the movements, and this apparatus has been the cause of not a few accidents. The more elaborate movements are only adapted for the practised athlete, and some of the finest displays of gymnastic skill are made with the trapeze.

The Hand Rings have a diameter of from 5 to 9 in., are placed about 18 in. apart when used by adults, and at a distance of 3 to 6 ft. from the floor. This apparatus is also very popular. The exercises closely resemble those carried out upon the trapeze. The same sets of muscles are concerned. The apparatus, if properly employed, is excellent for cases of lateral curvature; the lateral muscles of the trunk can be very fully and efficiently exercised, and one side can be especially developed if required.

The more elaborate exercises concern the muscles of the back and abdomen, and indeed the whole muscular system with the exception that the lower limbs are but little involved.

Unless care be exercised it is easy for young pupils to produce an unsym-

metrical development of the back muscles by an improper use of this appliance.

The Vaulting Horse is a valuable apparatus. The body should be from 5 to 6 ft. in length and should be capable of being adjusted at any height. Mattresses must be placed around it, and a sloping board is generally placed in front of it for leaping exercises.

The vaulting horse is well suited for children and the young and for athletic adults. It is scarcely the apparatus for the middle-aged. It may be used by girls under puberty, but its use in older females is open to some question (see page 593).

The exercises are varied, are pleasurable, and are popular with young people. It is well suited for class instruction. The simpler exercises consist of vaulting over the horse in different ways. The exercises develop all the muscles of the body, the lower limbs as well as the upper, the spine as well as the abdomen. Its use brings about a good grasp, a certain amount of agility and precision of movement, and cultivates a good swing of the body. It forms an excellent means of cultivating the respiratory apparatus and brings out the muscles about the pelvis.

One of the most popular lessons in a gymnasium is represented by a class of pupils who form in line and vault over the horse one after the other, keeping up a continued round and run.

The more advanced exercises are only suited for athletes and are elaborate and difficult. No gymnasium can be considered to be complete without some form of vaulting horse.

The Inclined Ladder as usually employed exercises mainly the muscles of the upper limb and upper part of the trunk. The exercises, like all other suspension exercises, are excellent for cases of weak back with tendency to curvature of the spine provided that they are carefully planned and supervised.

The apparatus affords good practice in balancing the body in the exercise of mounting the ladder with the feet only and is useful for developing the abdominal muscles. It is suited for pupils of various ages and of both sexes with certain limits.

The Ladder Plank is another useful and popular apparatus. The machine is made in many different ways. For adults the plank is about 18 in. wide, and from either side of it project spars which are 6 in. in length and 9 in. apart.

The exercises on this machine can be adapted to individuals of all ages, of both sexes, and of all degrees of muscular development.

The muscles of the entire body are exercised, although those of the upper limbs and of the upper part of the trunk receive most employment. Maclaren thinks that no machine in the gymnasium so rapidly and powerfully aids in the expansion and development of the upper part of the trunk as does the ladder plank.

This is a good form of apparatus for cases of lateral curvature of the spine; especially good are the exercises which involve the descending of the plank backwards, i.e. with the back to the plank. These exercises also throw the chest out to its utmost, and the apparatus is useful for the narrow-chested or pigeon-breasted. It is a valuable apparatus for growing girls and is safe.

The Horizontal Ladder gives opportunity for a good series of suspension exercises, which concern mainly the muscles of the upper limb, but which also develop, to a lesser degree, the muscles of the back and of the abdomen. This is another apparatus of service in cases of weak or distorted back.

Apparatus for Climbing.—Climbing affords excellent exercise, is very popular among children, is suited for pupils of both sexes and for individuals of almost any age. It is not suited for those who have not had special muscular training, nor for the corpulent, nor for those who are past middle life. All climbing exercises may be considered as advanced exercises.

Climbing may be effected in different ways, and children are very apt to acquire tricks in climbing which tend to distort the body and to develop it unequally. The movements of climbing must be carried out very precisely and methodically, and must be carefully superintended by the instructor. Girls and young women often make excellent climbers. The exercise concerns all the muscles, but especially those of the upper limbs. It also tends to develop the muscles of the thighs, back, and abdomen. It is not a good exercise for the subjects of spinal curvature.

The apparatus used comprises (1) the vertical pole, a smooth pole of any height, and with a diameter varying from two to three inches; (2) the slanting pole, which involves a combination of exercises represented by the vertical pole and the slanting ladder. This apparatus is of value in developing the muscles of the abdomen as well as those of the upper limb. (3) The turning pole is hardly suited for any but active youths and trained athletes. The exercises are difficult, involve much muscular power, and, above all, great dexterity, precision, and accuracy of movement. The apparatus consists of a slanting pole so adjusted as to revolve on its longitudinal axis. The great difficulty of the exercises consists in the maintenance of the balance on a pole which is not fixed. (4) The pair of vertical poles (two parallel poles placed eighteen inches apart) is an apparatus only suited for advanced gymnasts. The exercises are very arduous and demand great strength and much practice. They concern mainly the upper part of the trunk and upper limbs. (5) The vertical rope varies in length and has a diameter of from $1\frac{1}{2}$ to 2 inches. The exercises resemble those of the vertical pole, but are a little more varied and make more use of the lower limbs. (6) The Rosary consists of a vertical rope suspended from the ceiling, but not fixed at the foot, upon which are strung at intervals of from ten to eighteen inches elm heads, four inches in diameter and flat on the top. This affords good exercise in climbing for children—boys and girls—and for beginners. It employs all the muscles—those of the abdomen and back as well as those of the limbs—it concerns most particularly the muscles of the upper limbs. It gives exercise to the muscles about the hips and loins, especially if it be understood that the rope must always be kept in the vertical line. (7) The mast (which has a diameter of ten to twelve inches) is only suited for accomplished athletes.

The Giant's Stride.—This apparatus is more often found in the playground than in a gymnasium, and is seldom among the machines contained in the room. It affords good exercise for the muscles of the body, for the arms, the legs, the abdomen, and the back. The exercise interests children and the apparatus is always popular. It is useless, however, if the exercise be not regulated, and if children be not individually instructed in the simple but necessary movements. The children, moreover, should be about of the same size and if possible of the same state of physical development.

It is common to see children on the giant's stride whose movements are aimless and useless, who swing loosely about, and who either hamper the movements of the children behind them or are hampered by the struggles of the performer immediately in front of them. An undisciplined crowd of children who without instruction, selection, or arrangement try to gain enjoyment and strength from the giant's stride had better devote their energies to simpler pursuits.

Home Gymnasia

The so-called home gymnasium is usually more or less of a delusion and a snare. It is, as a rule, too elaborate to be of practical value, and too complicated for children's use. It often pretends more than it can accomplish. A swing, parallel bars, a knotted rope, and an inclined ladder form excellent elements in a home gymnasium, provided the children have been already well trained by means of simpler exercises.

A good machine for home use is an American invention, the so-called 'Excelsior' gymnasium. Here the power of the performer is exercised against weights attached to ropes passed through pulleys. The apparatus is capable of exercising all the muscles of the body, admits of almost endless combinations, and can be graduated to meet the needs of a child or an athlete. The rowing exercises on a sliding seat and the contrivance for developing the muscles of the back are in every way admirable. The machine is, moreover, strong, simple, and portable, and occupies but little space in a room.

The appliances which owe their main features to elastic bands are of limited use, are restricted chiefly to the development of the upper extremities, and involve a very monotonous form of exercise. A home gymnasium is a useful apparatus in a bathroom or bedroom, where it can be used every morning before or after the morning bath.

In concluding this part of the subject attention must once more be directed to the circumstance that *a proper and complete physical education cannot be carried out by means of apparatus.* Apparatus come last in a progressive system of physical training, and must always be used with great care and very sparingly. A large proportion of the exercises are totally unsuited for young subjects, and are only open to athletes or professed gymnasts. The tendency of the usual apparatus is to produce an unequal development of the body, to develop the muscles of the arms and shoulders and pectoral regions, and to neglect the muscles of the lower part of the trunk and of the lower limbs. In a subsequent section attention is drawn to the deformity produced by an excessive or exclusive use of the usual gymnastic appliances.

Outdoor Games

It is quite impossible to attempt to give any account of the particular value each of the many outdoor games may possess in relation to physical education.

In general terms it may be said that when played in moderation and under suitable conditions they are most excellent. They involve movement in the open air, very varied muscular exercise, a considerable amount of healthy interest and excitement, and the cultivation of a certain degree of skill and special adroitness. The parts that the great games of cricket and football have played in the development of the English people can scarcely be overrated.

These games not only involve healthy exercise and demand skill, but they require readiness of action, determination, foresight, sound judgment, and good temper. They tend to develop personal courage, self-reliance, the spirit of honour, and the impulses of loyalty. They cultivate all those qualities which make a man manly and wholesome in mind. If one wants to seek for the sneaks and cowards in a school, for the poor-hearted and unwholesome-minded, search must be made, not among the cricket and football teams, but among the loafers.

Cricket can be played at almost any age, and is as well adapted for young women as for young men. It is necessary only that the players should be as nearly equal in strength as is possible.

With regard to the game of football, I cannot do better than give two quotations from Mr. Shearman's admirable article in the Badminton Library volume. Before doing so it is needless to say that football as now played is a game which involves great skill and considerable intelligence. The heavy man who played 'forward' in days gone by, and who could stand a good hacking, and could hack in turn, is now no longer of any use in a football team. Other things being equal, the more intelligent the man, the better the player. In my opinion there is no outdoor game for lads and young men equal to football, whether it be the Rugby Union or the Association game.

Thus writes Mr. Shearman: 'For at least six centuries the people have loved the work and struggle of the rude and manly game, and kings with their edicts, divines with their sermons, scholars with their cultured scorn, and wits with their ridicule have failed to keep the people away from the pastime they enjoyed. Cricket may at times have excited greater interest amongst the leisured classes; boatraces may have drawn larger crowds of spectators from distant places; but football, which flourished for centuries before the arts of boating and cricketing were known, may fairly claim to be, not only the oldest and the most characteristic, but the most essentially popular sport of England.

'Football may be rough, may be at times dangerous; so is riding across country; so is boxing; so is wrestling. The very function and final cause of rough sports is to work off the superfluous animal energy for which there is little vent in the piping times of peace. Since football became popular with all classes, there have been less wrenching off of knockers and "boxing of the watch," and fewer "free fights" in the streets. Football has its national uses quite apart from the cheap enjoyment it has given to thousands. It may be rough, but it is not brutal.

'Next as to the danger. Doubtless there are accidents, and doubtless men have been killed upon the football field. But during a quarter of a century how many thousands of men have played, and have a score of these many thousands lost their lives? Fewer than those who have been drowned on the river, not a tithe of those who have fallen in the hunting field, are the victims of football. If the outcry against football because of its danger could be justified, not a single outdoor sport could survive.

'For every one who may have been harmed by football a thousand have benefited by it. Health, endurance, courage, judgment, and, above all, a sense of fair play are gained upon the football field. A footballer must learn, and does learn, to play fairly in the thick and heat of a struggle. Such qualities are those which make a nation brave and great. The game is manly and fit for Englishmen: "it puts a courage into their hearts to meet an enemy in the face."'

THE ELEMENTS OF PHYSICAL EDUCATION

1. *The exercises should be adapted to meet the needs of each individual case.*

It is to be borne in mind that the object of a proper physical education is to develop health and not strength, to bring the body to its highest degree of perfection and not to convert children and youths into gymnasts and acrobats, and that its main object is to best fit the individual for the duties

and work of life and not to elicit proficiency in mere feats of skill and adroitness.

It must not be forgotten, moreover, that individuals vary greatly in the quality of their physical powers and in their capacity for muscular exercise. It is just as impossible to form a great mass of children into one gymnastic class as it is to place those children in one school standard under one teacher. Neither age, height, size, nor sex affords sure means of classifying children, so far as the needs of a proper physical education are concerned. Each individual must be considered upon his or her own especial merits, and there is no method of physical training which is universal or all-sufficing and adapted for all sorts and conditions of human beings.

The sending of a child to a gymnasium, or the placing of it under the care of a drill-sergeant, is as crude a procedure as the conducting of a child within the walls of the first school met with, and leaving it there with the impression that it will somehow be educated. Physical education requires as much care as does mental education, and if there be ten 'forms,' or 'standards,' or 'classes' in a school which is concerned in mental training, there would probably be at least as many forms and standards in any institution which deals with the training of the body.

Instructors in gymnastics and so-called calisthenics are for the most part somewhat irresponsible beings; their training has often been narrow and incomplete, and their methods are fixed and inelastic. They regard their pupils in the aggregate and not as individuals. There are of course numerous striking exceptions.

It is to be hoped that a time will come when those who profess to train the body will be required to produce as definite evidences of fitness as is demanded of those who aim at training the mind.

One society in England—the National Health Society—has prepared a scheme for the examination of instructors in gymnastics and for the granting of diplomas and certificates to such as attain to the prescribed standard.

Such a scheme has been carried out in America, and serves, not only to do justice to competent teachers on the one hand, but to protect the public on the other. The National Health Society requires, among other things, that the candidate shall possess a certain knowledge of elementary anatomy, of the physiology of bodily exercise, of the various methods of physical training, and of the details of the various exercises and the uses of all gymnastic apparatus and appliances. The candidate is required, moreover, to produce evidence of physical fitness and of a proper training in some recognised gymnasium or training school.

The casual, perfunctory, and unmethodical manner in which physical training in many schools is carried out at the present day is very lamentable.

The need of a proper training is especially felt in girls' schools, in schools which are patronised by the lower middle class, and in the elementary schools controlled by the Education Act.

In the great public schools, and at the two great English universities, physical education is in a very flourishing and exuberant condition, and only in need perhaps of a little more method, a little more science, and a little more regard for the individual and the development of the feeble as well as of the strong.

The first necessity in physical education is a knowledge of the condition, the wants, and the possibilities of the individuals to be educated. This can only be obtained by an individual inspection. It would be well if in the elementary schools a plan such as the following could be carried out. Each

child on entering the school should have a book in which the following details should be entered :—

1. Name; 2. Age; 3. Height; 4. Weight; 5. General aspect and physique (the entries under this heading could be greatly extended and be made of much service if a competent medical man made the inspection); 6. Chest girth; 7. Breathing capacity; 8. Span of arms; 9. Girth of arms; 10. Drawing or pulling power as tested; 11. Girth of legs; 12. The existence of any evident deformity, defect, or disease. (This section could only be properly developed by a medical man. The conditions dealt with would be such as the following: spinal curvature, hernia, rickets, deformed thorax, stiff joints, infantile paralysis, enlarged tonsils, glandular disease, lung disease, condition of abdominal viscera, evidence of convulsions, &c.)

In this last section much could be done by a properly trained teacher, but a medical inspector would render the evidence in every way of greater value.

The child's physical condition should be inquired into with as much care as is exercised in examining an adult for life insurance. The urine should be tested if possible, and if the parents can be seen the child's family history should be inquired into.

Still, apart from an examination by a medical man, the twelve points prescribed would form the basis of a valuable record and place the physical education of the child upon a rational footing. Such a record should be kept also of all individuals attending gymnasia and undergoing any form of physical training. Upon the evidence afforded the precise exercises which were desirable and the precise methods of training to be carried out could be determined.

The record may well be extended, and could with great advantage record a test of the child's vision, and add evidence on the questions of astigmatism and colour-blindness. This record, kept in the form of a book, should be filled up every three months. If properly kept, the value of such a book would be enormous. To the individual it would possess more than mere interest. It would show the history of his early life, the record of his development, and would afford an admirable guide to any medical man should the individual in the future become the subject of disease.

Mental training is exceedingly important without doubt, but it may be that the time will come when the Government of this country will recognise the importance of physical training, and will realise that among the children in elementary schools a strong body is almost as important as, and often more useful than, a well-stored mind. Many of these children are turned out into the world pale, sickly, ill-developed, and feeble. That at present many unremediable causes may conspire to produce this is evident enough, but the state of things is susceptible of improvement. The health and strength and physique of the poorer classes may be placed upon a better basis, and a number of sturdy and strong men and women produced in the place of the multitude of poor creatures who after a more or less doleful and useless life become prematurely a burden upon the rates.

The systematic examination of the individual and the conducting of a physical education upon precise and scientific grounds have already been carried out in some cities in America.

An excellent account of some of these institutions will be found in the record of the Physical Training Conference held at Boston in 1889.

2. *The exercises should be carefully devised, systematically arranged, and suitably graduated.*

The course of education should be planned upon a definite system and

the classes formed, and when occasion demands remodelled, according to the physical status of the individual members.

The exercises must be graduated, and no attempt made to pass from one series until the more elementary stages have been mastered.

It is of especial importance than none of the more complicated, difficult, and arduous exercises should be forced upon those who are physically unfit. They must be always—from the learner's standpoint—moderate and progressive.

It is desirable also that the lessons should be as varied and as interesting as possible, and that reasonable opportunity be given for competition and the encouragement of those who are specially fitted to excel.

The exercises should aim at the equal employment of all the muscles, and not at the development of a few. The work in an ordinary gymnasium tends to throw strain mainly upon the upper extremities, while most of the outdoor games tend to develop the lower limbs. No great good can be obtained from tedious drilling and purposeless marching, and the time devoted to physical training should never be so fully absorbed as to allow no leisure for games and other pleasant forms of recreation.

In any instance violent intermittent exercises should be forbidden, and the performance of feats of strength should never come within the scope of the educational scheme.

3. *The exercises should be carried out under proper guidance, and with suitable and efficient apparatus.*

The teacher should be capable of instructing a large class—a qualification which is not commonly possessed.

4. *The time for the exercises should be carefully selected.*

Violent exercise after a full meal is obviously bad, and a course of physical instruction should not be carried out in the case of children who are tired from a long day's attendance in school, or who are feeble for want of food.

In the matter of schools it is well that the period for physical training should be interpolated among the hours devoted to ordinary school work. If between the hours of nine and twelve or nine and one the children could be allowed to take systematic exercise for thirty minutes, either in the open air or in some suitable building other than the schoolroom, they would be found to be actually refreshed by the change of occupation, to enjoy a period of mental rest, and to return to their work with vigour.

Another half-hour could be introduced during the progress of the afternoon lessons. The Rev. E. Warre, one of the masters at Eton, advises that a schoolboy's day should be disposed of as follows: Rest ten hours, work seven hours, meals and play seven hours.

So far as adults are concerned, the taking of violent exercise in the evening after a long and arduous day's work is often injurious in its result.

There is no time better than the early morning before the labours of the day are commenced.

Adults who have been accustomed to exercises of strength and endurance should return but cautiously to such pursuits if they have passed through a long period of rest from exercise and are out of condition. A man may ride fifty miles a day on a bicycle very easily in the autumn, but he would be very unwise to attempt such a distance in the following spring, provided that he had taken no exercise during the winter.

5. *Exercises, so far as is possible, should be taken in the open air or in a large and very well-ventilated room.*

6. *Those who are taking systematic exercise should be properly clad.*

The garments should be light, loose, and made of wool. It is desirable

that care be taken not to catch cold by standing about in clothes which are damp with perspiration.

This question of clothing is more fully dealt with in another section of this work.

Forms of Exercise

So far as any classification can be made—and it must of necessity be rough—exercises may be divided into the following classes :—

1. *Exercises of Strength*

These involve actual and considerable muscular power, and are illustrated by advanced exercises in the gymnasium, with apparatus such as the horizontal bar, the trapeze, the rings. In a special category may be placed what may be termed feats of strength, such as lifting great weights, putting the shot, throwing the hammer, and the like.

These exercises involve 'effort,' i.e. the muscular position in which the man takes a deep breath, and then, when his chest is full, closes his glottis, so that he may make the thorax a fixed base from which the upper limbs can act. During the performance of the movement he does not breathe, his face becomes engorged, and the veins which stand out upon his forehead demonstrate the distended condition of the right side of the heart. It is during 'effort' that some sudden and fatal accidents have occurred, such as rupture of the heart and the giving way of blood-vessels.

2. *Exercises of Speed or of Rapid Movement*

These include running in all its forms and such exercises as involve very rapid and continued movements. The individual muscular contractions are not extreme, but they are very quickly repeated. The amount of work performed is distributed over a considerable period, and is not, as in exercises of strength, concentrated into a few moments.

These exercises are susceptible of considerable modification, and range from the extreme effort of the sprint runner to the easier movements of the paper-chaser or of the devotee of the skipping-rope.

Certain forms of gymnastic exercise rank in this class. The movements tend to develop the respiratory capacity, and are the exercises which soon bring about the state of breathlessness.

3. *Exercises of Endurance*

In these the muscular effort is inconsiderable at any given moment, and is distributed over a still longer period of time.

Neither breathlessness nor rapid muscular exhaustion arrests the subject of the exercise. The continuance of his movements becomes a matter merely of endurance. Walking is a type of this variety. And in the same class must be placed many outdoor games, skating, rowing and cycling, drilling and such exercises as are generally included under the term Swedish gymnastics.

In the training of the body the exercises of endurance must occupy the first, the most prominent, and the most important place.

4. *Exercises of Skill*

are illustrated by the more complex gymnastic exercises, such as those which involve balancing, &c., by fencing and any other movements which imply, not necessarily severe or continued muscular exertion, but great activity of the brain and spinal cord.

The fencer in his earlier days becomes weary in his body, but as he becomes more experienced he 'feels' the exercise, not in his muscles, but in his nervous system.

5. *Exercises which Develop the Chest*

may on account of their importance be especially classified. The exercises which come under this class are such as tend to develop the muscles of the chest—namely, the pectorals, the serratus magnus, the latissimus dorsi, the anterior abdominal muscles, and some others of lesser importance.

This, however, is not all. As Dr. Lagrange has pointed out, the size of the thoracic cavity can only be increased by increasing the volume of its contents, the lungs. 'It is from within outwards,' writes that author, 'that the force capable of expanding the chest acts, and it is in reality to the lungs and not to the muscles, that the chief share in the changes in form and size of the chest belongs. The most powerful inspiratory muscles cannot raise the ribs, unless the lungs participate in the movement of expansion, and on the other hand the lungs can raise the ribs without the aid of the muscles, for the chests of emphysematous patients remain vaulted in spite of their efforts to lower the ribs and complete the respiratory movement. . . . Mountaineers all have large chests, and the Indians who live on the high plateaux of the Cordillera in the Andes have been noted for the extraordinary size of their chests. . . . Singers with no other exercise but singing acquire great respiratory power and a remarkable increase in the dimensions of their chests.'

The exercises needed, therefore, should not only be such as develop the muscles of the upper part of the trunk, but such also as increase the volume of the respiratory movements. Among the latter would be placed, so far as children are especially concerned, running, skipping, rapid limb movements, and active exercises in the open air.

Many children are born with deformed and narrow chests which they inherit from their parents; in others the thorax has been distorted by rickets, by lung affections, or by spinal disease. One potent factor in the production of a narrow chest, outside these causes, is the hypertrophied tonsil.

It is anomalous to press a child to take exercises requiring vigorous respiratory movements when enlarged tonsils so block up the opening into the air-passages as to prevent the free entrance of air.

The Selection of Exercises according to Individual Needs

Children

The physical training of children should be commenced early, should be made as interesting as possible, and be represented in the main by what may be termed scientific romping.

The exercises should be given whenever possible in classes. To set a child to execute formal movements with dumb-bell or bar-bell when alone, and to march with no one for company, is a little dismal.

The set exercises should not be too formal, and never be too long, and in no instance should they be allowed to take the place of the ordinary outdoor games of children.

Games which involve shouting should be encouraged, and a very prominent position given to running, skipping, games with balls, and jumping. The most rudimentary of all games, 'touch,' is one of the most excellent. The upper limbs may be encouraged by such amusements as battledore and shuttlecock and the lower by such a game as hop-scotch.

The set exercises should take the form of what are known as Swedish gymnastics, the vocal march, musical drill, and the class exercises with dumb-bell and bar-bell.

Children should avoid exercises of strength and, in the main, exercises of speed. They are best suited for exercises which involve moderate endurance and such as require no great mental effort to follow.

In the matter of gymnastic appliances there is little need of especial work. The subject is considered in the description of gymnastic apparatus. The principal of these, from the children's standpoint, are the climbing rope, the inclined ladder, the vaulting horse, the parallel bars.

Girls and Women

The physical condition of a large proportion of the girls and women in this country is quite deplorable, especially among the middle and upper classes. A well-developed perfectly proportioned girl who is possessed of normal muscular strength, who can walk naturally, and can carry herself with grace, attracts attention. The wretched physical state of a large proportion of modern girls—especially of those who inhabit the large towns—is apt to be ascribed, not to a totally neglected education, but to the belief that growing girls are always awkward, uncouth, and weedy. This belief is not well founded.

The unfortunate girl is encouraged to be dull, to be prim, to be subdued, to suppress the outbursts of pure animal spirits. She is more or less under the curse of that detestable adjective 'lady-like.' She spends hours in an ill-ventilated schoolroom and upon a piano stool, and the rest of her time is occupied in eating and sleeping, in preparing lessons, in stooping over needlework, and in taking formal walks with the governess. Her clothes are probably a collection of hygienic errors.

It is not to be wondered that a girl so fostered is often a melancholy specimen of her species. She may be highly educated and the mistress of many accomplishments, she may be cultured and 'refined' according to the boarding-school standard, but she will at the same time be probably more or less unfitted for the struggle of life and the mere circumstances which attend living.

There is something about the 'higher education' of the modern girl which is comparable to the manufacture of the finest Sèvres china. The result is beautiful from the designer's standpoint, but the cup is delicate; it cannot be used in daily life, and it must be kept in a cabinet.

A good digestion and an active liver are more useful in the battle of life than a knowledge of advanced mathematics, and sturdy limbs and strong hands are of more value to the mother of children than even decimal fractions and a familiarity with irregular verbs.

The lady-like girl is encouraged to keep her hands 'fine,' to have them compressed by gloves and protected from light, and to use them as little as possible in order that she might produce the wan, feeble appendage which constitutes the lady-like hand, and which is put to little more use than to set off a few rings. The face must be protected from the sun by sunshades and veils, the pink and white complexion of the invalid must be imitated. It would appear that the lady-like are always delicate, and a certain unobtrusive feebleness and flabbiness are signs of refinement. For use and influence in the world, for a capacity to enjoy the purest pleasures of life, and as an example of all the finest qualities of womanhood, no one among the 'higher educated' can compare with such an one the 'Nut Brown Maid.' The ballad of the 'Nut Brown Maid' might well be engraved upon the wall of every 'finishing' school for young ladies.

A neglected physical education produces a sorry object—a pale child with a poking head, a narrow chest, an unshapely back, a shuffling or mincing gait, and an ungainly carriage. She is without grace and without the capacity for vigorous physical enjoyment. Her ankles and wrists are clumsy, her complexion is dull, and if her circulation be bad—as is not unusual—her sodden-looking purplish arms are covered with a fine down. When she grows up to womanhood she finds herself unfitted for the duties and responsibilities of a wife and mother. She has little strength to withstand the hardships of life and less capacity to enjoy its pleasures. She is nervous, querulous, frail, and in more respects than one a poor creature. Walking makes her tired, the sea makes her sick, the sun makes her head ache, the wind makes her chilly, effort of any unusual kind reduces her to a general wreck. The number of women who can travel without fussing and knocking up, and who can climb a ship's side and make their way across a heavy moor, and can, indeed, become companions to their husbands and brothers in the milder of these outdoor sports is not considerable.

Younger girls may pursue the exercises named in dealing with the education of children. Those who are a little older have an infinite variety of healthy pursuits at their service—running, skipping, outdoor games of all kinds, riding, skating, swimming, cricket, games with balls, archery, tennis, climbing (in a moderate form), and certain exercises in the gymnasium. They should practise also such movements as develop the abdominal muscles and should never neglect rowing.

Fencing in moderation is admirable; a tendency to flat feet and weak ankles may be met by such simple games as hop-scotch, by dancing (in the open air), by learning Scotch dances and the hornpipe. Cycling may, I think, be avoided, and I am under the impression that jumping may well be dispensed with in girls who have passed the period of puberty.

For women such exercises as have been just detailed are open, with the obvious modifications which their age and dispositions suggest.

Rowing is an admirable exercise for women up to almost any age.

The matter of clothing need only be briefly alluded to. It is of little use to expect great good from walking exercises if tight boots are worn, with high ankles and high heels. Corsets are an abomination, and rowing in corsets forms a means of developing a pendulous abdomen and the conditions which lead to hernia.

Lads

between fourteen and eighteen have almost every form of exercise and physical recreation open to them. They should avoid exercises of strength and feats of strength and exercises of extreme speed such as sprint running.

Adults

between eighteen and twenty-five have the whole of the joys of the athletic world open to them, and if a man keep in training and in practice his period of athletic life may be extended to thirty.

The Middle-aged and Elderly

must anticipate a progressive curtailment of their more active pursuits. There remain, however, walking and all the milder forms of outdoor exercise—riding, skating, cycling, and the use of the simpler gymnastic apparatus. After thirty very few individuals indeed are capable of undertaking exercises of speed without actual risk.

BATHS

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BATHS

HISTORY OF BATHS

It is altogether beyond the scope of an article such as this to give a history of baths. It would occupy too much space, and much of it would be uninteresting to the medical reader. It will, however, be worth while to give a short sketch of the history of baths so far as it concerns the student of medicine.

Bathing is as old as the hills; we find evidences of it far back in history, and at the present day savage tribes often attach great importance to the curative effects of water. It is the custom of the Fiji women to take a sea bath immediately after their confinement, with the object of accelerating their recovery. The belief in the healing efficacy of water is sometimes so strong that it becomes a religious belief. Thus we have the practice among the Hindoos of bathing in the Ganges, or in the sacred lakes around their temples; we have the baths of purification ordered by the law of Moses, and they are also required by the Talmud and by the code of religion of the Mahommedans. The story of Naaman is another instance of the old belief in the medicinal virtues of baths. In the traditions of the mythical period of Greek history we find abundant allusions to the practice of bathing. Later we find Hippocrates writing on the subject. In his work on 'Air, Water, and Places,' that on the 'Usage of Liquids,' and also in that on 'Diet and Regimen,' there are exact directions as to the employment of water in therapeutics. Among the Romans bathing reached great perfection: for a full description of all their baths the reader may consult the article on 'Baths' in the 'Encyclopædia Britannica.' Musa and Charmis were the two physicians who most advocated the work of baths in medicine. Musa attained great fame because Augustus recovered under his care, and part of the treatment was the use of cold water thrown over the body after warm baths and vapour baths. Under Charmis the use of cold baths became very popular, and Pliny gives an account of the Roman senators who sat shivering after the cold baths which Charmis had ordered them. He employed them with such rigour that a controversy sprang up as to whether they were really so useful as he contended, and for a time they were not popular. Galen advocated cold baths, but condemned their excess, and recommended the use of cold water to the head while the body was in a warm bath. During the medical barbarism of the Middle Ages baths fell into disrepute.

Among the Arabian physicians, Rhazes alone advocated cold baths, and he advised their use in the treatment of small-pox, and used rose-water for burns. It is not until 1699 that we again find baths attracting the attention of the medical profession. In that year Floyer, an English physician at Lichfield, published his book entitled 'An Inquiry into the Right Use of Baths,' and he recommended many applications of them.

In the eighteenth century the chief interest in baths was seen in Italy, and one historian of the period states that 'all Italy is crazy on the subject of cold water.' At the same time the Hahn family in Germany, consisting of two brothers and a son, all strongly recommended the use of cold baths

for various medical ailments. Johann Sigismond Hahn published a work on the subject in 1743. He applied cold water to the treatment of fevers, especially small-pox, measles, and erysipelas, and used it also for many chronic diseases. In Russia, likewise, the use of baths became fashionable.

France also took up the movement. Surgeons, reviving the practice of Ambroise Paré, advised the use of cold water for the treatment of wounds. The most ardent French advocate for cold baths was Pomme, and he treated all diseases of the nervous system by placing the patients in cold baths of a temperature of 50° F., and leaving them there for from six to twenty-four hours. His theory was that by the cold baths he infiltrated the nerves with water, and thereby drove the disease out of them.

The first physician who treated the subject of baths at all scientifically was Currie, of Liverpool, who, being on board ship with Dr. Wright, of Edinburgh, when the latter had typhus fever, treated him by throwing buckets of cold water over him. Dr. Wright was so much improved by this treatment that Currie was led to adopt it in many forms of fever, amongst others typhus, small-pox, scarlet fever, and measles. He was very successful, and published in 1797 his medical reports on the 'Effects of Cold Water in Febrile Maladies.' This book sold largely, for it soon reached its fourth edition. The great merit of Currie's work was that he observed accurately how much the application of cold reduced the symptoms of fever. Shortly after him Giannini, in Italy, used cold water for fevers. He preferred the cold bath, while Currie had used cold affusions.

In 1789 Vincent Priessnitz was born in Silesia. He was of very humble origin, and had no scientific knowledge. When about twenty he broke his ribs, and he treated himself by the application of a cold water bandage. The ribs healed, and he attributed the cure to the action of the cold water. He then roamed all over the country treating human beings and animals by cold water in a most haphazard manner, quite irrespective of the maladies from which they might be suffering. The peasants attributed his success to sorcery, but, anyhow, he became immensely popular, and the little village of Greifenberg, where he settled down, soon became a town full of hotels to accommodate the thousands who came to be treated by him. The Austrian Government appointed a medical commission to examine the subject, and they reported favourably upon the treatment of certain diseases by baths, and thus, although Priessnitz was an ignorant quack, he became the means of bringing the subject of baths before the medical profession. He amassed an immense fortune, but left no record of any scientific value.

From that time till now such an impetus was given to the subject that baths have become very popular. It is true that between about 1825 and 1860 there was a temporary lull in some branches of the subject; but since the latter date the work of scientific men, such as Liebermeister, Jürgensen, and others, has thoroughly elucidated the subject. In the following pages we shall see that, although baths are of great value, their importance has been immensely overrated by all sorts of impudent quacks, who issue pretentious advertisements designed to attract persons to particular bathing establishments in which these quacks have a pecuniary interest.

FORMS OF BATHS

Baths are divided into general and local. A general bath is one in which the whole body, save the head, is immersed. A local bath is one in which only some part of the body is immersed. The local baths which have re-

ceived names are the occipital bath, the elbow bath, the hand bath, the sitz or hip bath, and the foot bath. Sometimes the word 'bath' is used even when no part of the body is immersed; thus we have a shower bath. Closely allied to baths are those local applications of water in which it is made to play upon a part of the body in the form of a spray or douche. There are a great many varieties of these at all bathing establishments. The water is generally projected upon the part with considerable force, and its temperature is capable of being modified while the douche is in action. Sprays and douches have been named either according to the part of the body to which the water is applied, such as the rectal douche, the vaginal douche, or according to the shape of the stream that is ejected. There is no need to recapitulate all the foolish and fantastic names that have been thus applied. Water may be locally applied to parts without actually coming in contact with them. It is then solely used to produce local alterations in temperature. Leiter's coils are an instance of its employment in this manner, and various sounds, elastic bags, or catheters, through which cold or warm water is made to circulate, have to be used in the treatment of diseases of the uterus, vagina, rectum, and urethra. Water in the form of ice is applied to parts by being placed in india-rubber bags which are placed on the skin; Chapman's spinal ice-bag and the ordinary ice-bag applied to the head for concussion are instances of its use in this manner. Lastly, it is frequently applied locally by means of cloths, flannels, or lint, rinsed out in hot or cold water, which then forms either a compress or a fomentation. If these are covered over with gutta-percha, they retain the heat of the body, and so act like a poultice.

The Physiological Action of Baths considered according to their Temperature

We shall have under this heading to consider the influence upon the body of (1) indifferent baths or those in which a healthy person feels neither hot nor cold; (2) cold baths or those in which a healthy person feels cold, and (3) warm baths or those in which a healthy person feels warm. Popular terms used for varieties of these will be mentioned under each heading. Delmas gives the following table showing the temperature of water baths, which are named according to their temperature:—

	Deg. Cent.	Deg. Fahr.
Excessively cold	0 to 6	32 to 42·8
Very cold	7 „ 10	44·6 „ 50
Cold	11 „ 15	51·8 „ 59
Moderately cold or fresh .	16 „ 20	60·8 „ 68
Slightly cold	21 „ 25	69·8 „ 77
Tepid	26 „ 30	78·8 „ 86
Warm	31 „ 35	87·8 „ 95
Very warm	36 „ 40	96·8 „ 104
Excessively warm . . .	41 „ 60 or 70	105·8 „ 140 or 158

All people are not equally sensitive to the effect of heat and cold, so that no precise classification can be given.

Indifferent Baths

Water is a very much better conductor of heat than air. From this it follows that the indifferent temperature of water is much higher than that of air. In a perfectly still atmosphere a naked person feels neither hot nor cold if its temperature be somewhere between 67° and 77° F.; but the indif-

ferent temperature of water varies for different persons from 88° to 98° F. An indifferent bath, however long its duration, produces no alteration in the bodily temperature. After it there is a pleasant feeling all over the body, and there may be a slight loss of heat from the evaporation of the water that has been left on the skin, and therefore it is always advisable that the bather should dry himself quickly after the bath. There is no alteration in the amount of urea and carbon dioxide subsequently excreted; but the amount of urine passed is said to be sometimes slightly increased. The pulse and respiration are unaltered. Some authors state—but, as we shall see later on, without sufficient evidence—that the skin is capable of absorbing water from an indifferent bath. Water being so much denser than air, the total pressure on the surface of the body must be considerably greater in a water bath than in the air; but we do not know of any effects that can be attributed to this. An indifferent bath is often popularly called a warm bath, while one intermediate between warm and cold is spoken of as tepid.

Cold Baths

A cold bath abstracts heat from the body just the same as it would from anything else with a higher temperature than the water of which it was composed. But with healthy individuals taking an ordinary cold bath, the loss of heat is not demonstrable by the thermometer, for the production of heat is increased. In apparent contradiction to this statement is the fact that Maclister ('The Nature of Fever,' 1887) has shown that cold has the effect of abolishing, or at any rate greatly diminishing, the thermogenetic function of muscle. But then it must be remembered that he used extreme applications of cold. Thus in one of his experiments he found that when an animal was cooled 16° C. the power of its muscles to produce heat when stimulated was almost abolished; but that when it was warmed up again to the former temperature the thermogenetic power returned. Frédéricq and Quinquand (quoted by Dujardin-Beaumetz, 'Therapeutic Gazette,' Feb. 1888) state that in a healthy individual taking an ordinary cold bath, owing to the contraction of the cutaneous vessels the blood, and consequently the muscles, are but slightly cooled, and in such a bath the absorption of oxygen, the elimination of carbonic acid gas, and thermogenesis are increased. This effect is most probably due to the stimulation of the skin by the cold water, and the consequent reflex affection of the nerves which preside over the thermogenetic function of muscle—that is to say, over the decomposition of its thermogen, a term which has been applied to such substances in muscle as produce heat. These same researches of Frédéricq and Quinquand show that if the application of cold be very prolonged, or if the cold be very great, the absorption of oxygen and the excretion of carbon dioxide, which may be taken as indications of the amount of thermogenesis, fall below the normal point, thus really confirming Maclister's statements. The radiation of heat must be considerably diminished by immersion in cold water; but there is no evidence to show how much it is affected by a bath. Probably all these conclusions are not precisely applicable to a patient suffering from fever, although, no doubt, in the main the same considerations will apply; but owing to the dilatation of the cutaneous vessels which so commonly exists in fever, the blood is cooled and thus the thermogenetic function of the muscles, owing also to their being likewise quickly cooled, is sooner depressed than in health. But, even in a fever patient, the first effect of a cold bath is probably at first to increase thermogenesis; but soon the activity of this function decreases, and it may continue to be considerably depressed even for some time

after the patient is taken out of the bath. For a fuller account of the application of a cold bath for fever the reader is referred to the writer's 'Textbook of General Therapeutics.'

The effect of a cold bath upon the actual temperature of the body has been carefully studied by many observers. If the bath is moderately long and not very cold, the bodily temperature remains constant because of the balancing of the loss and of the production of heat. Liebermeister in 1859 showed that if the bath be very cold the internal temperature rises slightly. For example, he found a slight rise of the rectal temperature was caused by a bath of 86° F. lasting twenty-five mimutes. Jacob, Kemig, and others have confirmed these results. In one experiment the temperature of the blood rose as much as 3°·6 F.

Probably, however cold the bath, there is at first a slight rise of the internal temperature; but, if the water be very cold, this is too transient to be noteworthy, and we get only a sinking of the whole temperature of the body, both external and internal. The same effect may be produced by a moderately cold bath if it be continued sufficiently long. Thus Jürgensen found that long-continued baths of a temperature of 50° F. usually caused a rapid sinking of the temperature of the body. Liebermeister says that most persons can bear baths of a temperature of 68° F. to 75° F. for, on the average, twenty minutes before their temperature sinks below what it was previous to the commencement of the bath. The fall of temperature is naturally greatest on the surface and least in the interior and in the folds of the skin. For example, in one of Jacob's experiments the temperature of the skin sank in a cold bath lasting sixteen minutes from 62°·6 to 48°·2 F., but that of the axilla only sank 1° F.

After the discontinuance of a bath which was not sufficiently cold, nor long enough to cause a fall of the bodily temperature, there is a short period during which it falls a little lower than before the bath. This is called by Liebermeister the primary after-effect. The slight rise of temperature which succeeds this is called by Jürgensen the secondary after-effect. The primary after-effect is due in part to the fact that the cutaneous vessels which were contracted during the bath rapidly dilate again when the bather leaves it, and thus there is a greatly increased radiation of heat, the effect of which in cooling the bodily temperature is augmented by the diminution of heat-production which, as Liebermeister has shown, directly follows the leaving of the bath and is probably to be looked upon as compensatory to the increased heat-production which took place during it. The following figures from Leichtenstern show the great loss of heat occasioned by a cool bath. He says, if we observe in a man who is healthy and not unnaturally stout the loss of heat which takes place in a bath of the duration of fifteen to twenty-five minutes, it is found that in a bath of 93°·2 F. the loss of heat nearly corresponds with the ordinary average loss; in a bath of 86° F. it reaches twice, in a bath of 77° three times, in a bath of 68° F. more than five times the average loss.

Local withdrawals of heat, such as partial baths and cold douches, have the same effects, but to a less extent.

All authors are agreed that a cold bath greatly augments the tissue-waste in the body. Braun says that the amount of carbon dioxide excreted may sometimes be increased as much as from 300 to 500 per cent. Roughly speaking, this increase is proportionate to the increased production of heat. Liebermeister found that in a bath of only 90°·3 F. the excretion of carbon dioxide was slightly increased, but with a bath of 64°·4 F. it was increased to three times the normal amount. The increase in the excretion of carbon dioxide continues for a short time after the patient

leaves the bath. This is due in part at least to the fact that the increase in excretion will continue to be evident for some little time after the increased production, which is the cause of the greater excretion, has stopped. Röhrig and Zuntz have both of them shown by means of their experiments upon rabbits that this increase in the excretion of carbon dioxide is accompanied by a corresponding increase in the amount of oxygen taken in.

If the bath be so cold or so long that the temperature of the body begins to fall, then the increased excretion of carbon dioxide gradually lessens, till at last the amount excreted may be even less than it was before the bath. Here also the amount of oxygen taken in decreases proportionately to the diminution in the amount of carbon dioxide excreted. These variations in the excretion of carbon dioxide are directly caused by the variations in the production of heat, which, in their turn, are due to a greater or less decomposition of thermogen, owing to the reflex stimulation of the nerves of skin by contact with the cold water. Experiments made upon animals give the same results as observations upon man. Many observers have worked at the subject. Röhrig and Zuntz and Colasanti used rabbits, Finkler employed guinea-pigs, and Duke Carl Theodore used cats.

A local application of cold produces precisely the same effects upon tissue-metamorphosis as does a cold bath, but they are less in amount.

Leichtenstern says that excretion of urea is not altered by a cold bath unless the temperature of the body is considerably lowered by it. The following authorities agree with him in this statement. Liebermeister found, in experiments he made in 1859, that cold baths produced no alteration in the amount of urea excreted, if the patients remained on the same diet. Senator experimented with dogs, and came also to the conclusion that a diminution of the external temperature produced no change in the excretion of urea. Voit's experiments gave a like result. Probably, if the cold be very great or very prolonged, the excretion of urea may be altered. Braun simply states that a cold bath increases the excretion of it, without saying at what temperature this takes place.

Turning now to the effects of a cold bath upon circulation and respiration, the most obvious result is that the cutaneous vessels will be contracted. If the bath be excessively long continued or very cold this contraction is succeeded by a paralytic dilatation, and this accounts for the bluish-red colour of the skin so often seen after a cold bath. The contraction of the vessels is probably due in part to a reflex and in part to the direct stimulus of the cold water. Observations upon the rate of the pulse are very discordant, some authors stating that it is quickened, others that no alteration takes place, and others that it is slowed. The explanation of these discrepancies is that at first the pulse is slightly accelerated, but subsequently it is retarded. The primary quickening is often but slight, or it may be unobservable; probably it is due to the rise in the blood-pressure caused by the contraction of the cutaneous vessels. The exact temperature necessary to cause a marked slowing is not the same for all persons. Kirejeff could not detect any effect upon the pulse after a bath of 71°·6 to 75°·2 F., but Kemig found that a regular diminution of pulse-rate was produced by baths of a temperature of 95° F., and Draper found after a cold bath lasting an hour and composed of water at a temperature of 74° F. that there was considerable slowing of the pulse, which retardation remained for some little time after the cessation of the bath. Probably the blood-pressure rises a little when the cutaneous vessels are contracted by the cold bath and falls when they are paralytically dilated, but we have no experiments in proof of this.

With regard to respiration, the first effect of a cold bath is that the

bather, if the water be sufficiently cold, gasps and experiences a sensation of difficulty of breathing. At the same time he feels a shiver run all over him. This is accompanied by a long-drawn inspiration which may deepen into a sigh. Then there is a sudden stoppage in respiration, due in part to a spasmodic closure of the glottis. This, however, soon passes off and there is a prolonged expiration and, in extreme cases, a groan. With healthy persons it takes a considerable degree of cold to produce these effects, which are witnessed after much less cold in children and sickly people. The frequency of the respirations is at first a little greater, but soon they are considerably slowed. This is true both of man and animals. Leichtenstern says that all observations agree that the amount of air respired increases in a cold bath. In one of his experiments a rabbit was immersed in water at a temperature of 53°·6 F. During a bath of fifteen minutes the volume of air breathed was increased 25 per cent. It is clear that if the number of respirations is diminished their depth must be enormously increased.

After a little while the condition of goose-skin is seen; this is probably due to a contraction of the arrectores pili.

Weber has shown that very cold baths diminish the cutaneous sensibility. This, however, does not apply if the stimulus be a warm substance, for the colder the skin the greater is its power of distinguishing warm bodies when they are applied to it. If, however, the degree of cold be moderate, cutaneous sensibility is at first raised, and stimuli which ordinarily could hardly be felt are painful. The property possessed by cold water of stimulating the peripheral nerves is frequently used to accelerate the return of consciousness in persons who have fainted. After a cold bath of short duration there is, as is well known, a feeling of well-being and exhilaration. The bather is refreshed. The mental faculties are cleared, the muscles seem strengthened, and there is a desire for both muscular and mental work.

If the bath be very cold, or the bather stop in it a long while, the bladder and rectum may be emptied reflexly and he may experience partial paralysis of the muscles of the body, together with a general sense of weariness and mental weakness.

The feeling of well-being which follows a short bath is usually explained by the fact that, owing to the contraction of the cutaneous vessels, there will be more blood in the internal organs and consequently a more rapid removal of waste-products from them, and an increased stimulus to their functional activity. On the other hand, if the cold be sufficiently prolonged to paralytically dilate the cutaneous vessels it is obvious that, owing to there being less blood in muscles and other internal organs, waste-products will accumulate in them, and the amount of blood in them will be diminished. The feeling of warmth after leaving the bath is to be attributed to the reactionary dilatation of the cutaneous vessels, which is subsequent to their contraction. If there is no feeling of warmth it may be that either the vessels of the skin have not contracted, or that they have dilated because they are paralysed by the cold, or that, having contracted, they will not expand again on leaving the bath. There are many individual peculiarities in these respects. Bathers must always be careful not to take a bath so prolonged, or of a temperature so low, as to prevent the reactionary dilatation of the cutaneous vessels. A patient feels the after-effects of a cold bath more if he has just had a hot one and *vice versâ*.

Cold baths are largely used for the exhilaration that ensues, which can be increased by rubbing with a rough towel. If they are taken constantly, the alternate contraction and relaxation of the vessels train them to contract easily, and therefore habitual bathers are not very liable to catch cold.

We will now discuss some of the more important effects of the local application of cold water by means of local baths, douches, sprays, &c. Our most accurate information on this subject is due to the labours of Winternitz. He used the plethysmograph and showed that when cold was locally applied to any part—for example, the middle of the arm—there was a diminution in the size of the vessels, of the quantity of blood, and a lowering of temperature in the parts beyond the point of application, and the reverse in the parts behind. One of Winternitz's figures showing the great diminution in the size of the radial pulse-wave after the application of cold to the arm is very striking. Its amplitude is diminished by quite three-quarters. Other figures of plethysmographic tracings show most markedly the diminution in the size of the arm produced by immersion in cold water. When the area of the body to which the cold is applied is considerable, the local vascular contraction is accompanied by a universal dilatation of the vessels all over the rest of the body. This fact Winternitz has proved with the plethysmograph, by which instrument he obtained a tracing which showed most markedly the increased volume of the arm due to a sitz bath at a temperature of 46°·4 F. The temperature of the axilla was at the same time raised.

The local application of cold has another important effect, namely, that it produces a reflex contraction of distant vessels. Naumann separated all the parts of the posterior extremity of a frog so that the limb remained attached to the body only by the sciatic nerve. He then applied cold to the leg, and observed that if the cold were moderate there was a diminution in the capillary circulation of the mesentery, but when the application of cold was prolonged there was a dilatation of the vessels. Schuller, in the same way, showed that the application of a moderate degree of cold caused contraction of the vessels of the pia mater; the application of an extreme degree caused dilatation of the same vessels. Franck, working with the plethysmograph, showed that the application of cold water to one hand produced a decrease in the size of the vessels of the other. These experiments have been confirmed by Mosso. All these effects are undoubtedly reflex, and some experiments of Winternitz are very interesting as showing an association between different parts of the body. Thus he found that the application of cold to the feet influences chiefly the intra-cranial circulation, cold to the thighs affected chiefly the pulmonary circulation, and cold to the back especially influences the circulation of the vessels of the nose. This fact is very interesting in connection with the popular practice of putting a cold key down the back for epistaxis. These reflex effects of cold applied to the skin in contracting deeply placed vessels have many applications in medicine: thus we apply an ice-bag to the head for concussion, and ice-poultices to the chest for pneumonia. Some find a cold sitz bath useful for diarrhœa. Another reflex effect of the local application of cold to the skin is that at first the pulse and respiration are increased in frequency, afterwards they diminish. If the cold be very severe there may be much palpitation and gasping.

Cold feet can be warmed by the reaction after a cold foot bath, and menstruation can in some women be checked by the same means. The many applications of cold for various medicinal purposes, chiefly to reduce inflammation, hardly come within the scope of the present article. It is said that cold baths increase the number of the red blood-corpuscles and the amount of hæmoglobin in them, and for this reason some advise cold baths for anæmia.

Cold baths are contra-indicated in all who do not react rapidly after them. Therefore they should not be ordered for the very young, the very old, or those debilitated by disease, nor for those in whom there is already congestion

of the internal organs, unless it be with the object of producing a reflex local effect. All baths, save those which are temperate, are forbidden for persons with disease of the heart.

Warm Baths

It is usually supposed that the temperature of the human body remains constant even if the variations of that of the surrounding medium are extreme. But we usually forget the important influence exercised by our clothes in maintaining the average temperature of the body. It has been undoubtedly shown that, if we consider the naked body, its temperature is constant only within certain narrow limits. To speak more accurately, we ought to say the temperature of the folds of the skin, for most of the observations have reference only to the axillary temperature. Senator observed the effect of undressing in a room and found that it reduced the axillary temperature slightly, even when the room was of the usual temperature of 60° F. or between 58° and 70° F., and he comes to the conclusion that the axillary temperature is only constant if the body is naked when the surrounding temperature does not differ more than from 14° to 18° F. from that of the body. Winternitz has performed a number of experiments and has shown that alterations in the temperature of the air only affect the temperature inside the clothes slightly, unless the alteration be about 50° F., so that, although in ordinary life man's temperature is constant, that is due not only to the adjustment of it but also to the fact that the temperature next to his skin is fairly constant. We have already seen that a cold bath will alter the temperature of the body, and from what one has just learnt we are not surprised to find that a warm bath will do the same.

A warm bath, therefore, increases the temperature of the body both by imparting heat to it and preventing the loss of warmth from it. Zuntz and Röhrig put a dog for eighteen minutes in a bath at 107° F.; the animal's temperature rose 4° F.; and Seiche and Schmelkes have obtained similar results. Liebermeister found that if the water of the bath was at the temperature of the body, so that no heat was given off, the temperature in the axilla rose. Thus, in one experiment, in 55 min. the temperature rose from 99°·[illegible] to 102° F., and in another similar experiment it rose from 99° F. to 102°·4 F. Mosler observed in hot baths of 104° to 111°·2 F. that the temperature of the mouth would rise to 101°·6 F. After the bath is over the temperature gradually falls again. It may be urged that in Turkish and Russian baths the temperature of the body does not rise in anything like the proportion of that the above figures indicate, but it must be remembered that a hot-water bath prevents loss of heat from the body almost completely, for there can be no loss by evaporation, none by conduction, and very little, if any, by radiation. In a vapour bath, unless the air is saturated, evaporation of the sweat from the skin-evaporation can take place. Still, the temperature of the body does rise considerably in a vapour bath. Bartels gives an experiment in which in a vapour bath of 127°·4 F. the temperature of the body rose in 10 min. from 100°·4 to 104°·5 F. On another occasion, in a vapour bath of 123°·8 F. the temperature of the same individual rose from 100°·4 in 8 min. to 103° F. in 30 min. to 107° F. Many other observers have published results which accord with these. In a Turkish bath the temperature of the body may rise a little in the hotter rooms, but owing to the rapid evaporation of the sweat the rise is very slight. Kemig has attempted to find out whether there is any alteration in the production of heat in a patient taking a hot bath, but the experiments are not sufficiently accurate and we have no evidence on the matter. The exhalation of carbon dioxide and water

from the lungs is increased, but because that of the oxygen is diminished the total quantity of respired air is lessened. According to Braun, if a warm bath be very long continued the blood becomes thick and dark-coloured and there is a continuance of the greater oxidation at the expense of both the blood and the tissues. Winternitz states that the changes in the urea are the same in both hot-water and vapour baths, but that the increase in the excretion of it in water baths is less than it is in vapour baths. Naunyn found that in dogs whose temperature had been artificially raised the amount of urea excreted was augmented, and Bartels observed that in men who took warm baths the amount of urea was increased. Schleich made a most careful series of experiments in which a uniform diet was maintained throughout. On certain days the temperature was raised to 103° F. by means of hot baths: on these days there was always an increase in the urea excreted; this continued for some days after the bath, but gradually decreased, and at last was succeeded by a compensatory decrease of urea.

It is said that there is an immediate momentary fall of the pulse in the hot bath; but this is very quickly followed by an acceleration. In one of Kemig's experiments a bath at 99° F. caused a rise in the pulse from 80 to 96 beats, but a cold shower bath brought it down rapidly to about 74. The rise in the rate of the pulse is always proportionate to the rise in the bodily temperature. Owing to the wide dilatation of the cutaneous vessels there is a fall in the blood-pressure of internal organs.

Many experiments have been made with regard to the influence of warm baths upon respiration, and, although some of them are discordant, all the more accurate show that the respirations increase in frequency proportionately to the rise in the temperature of the body. This is true not only of hot-water baths but also of hot-air and vapour baths.

After leaving the bath the skin is red and the secretion of sweat is enormously increased. Hot water liquefies the fatty secretions of the skin, and is a better solvent than cold; therefore it cleanses the body more thoroughly.

After a hot bath the secretion of urine is lessened, just as after a cold bath it is increased. In certain cases it is said to be slightly increased for a short time after even a warm bath, but it is doubtful whether in such cases there is really an increase in the secretion; probably the general muscular relaxation produced by the warm bath gives rise to a desire to void the urine. Koloman Müller counted the drops of urine leaving the ureter from shaved dogs. When the dog was put in water at 104° F. the secretion of urine was decreased; but under the influence of cold water it was increased by from 5 to 11 drops in each five minutes. It is said that after a prolonged warm bath the urine is rendered alkaline, but Leichtenstern and Röhrig deny this. The following summary of the chief effects of warm baths is taken from the writer's 'Text-book of General Therapeutics.'

Owing to the dilatation of the cutaneous vessels blood is withdrawn from the internal organs, and thereby their functional activity is depressed. This explains many uses of hot baths; one taken immediately before going to bed has long been known to be a valuable remedy for insomnia. The soporific effect of a warm bath has been known to cause the death of the bather. Frequent warm baths are enervating. Great weariness of the muscles is relieved by a hot bath, probably because by withdrawing blood from them it lowers the activity of the processes going on in them. Napoleon, if possible, always took one when he was unable to get a night's rest. Braun lays considerable stress on the chemical changes in the tissues and the blood that the rise of temperature produces, and some authors believe warm baths

to have an absorbing power over inflammatory products, but these matters are very difficult of proof.

The effects are often not the same on different individuals, but for nearly all persons the following propositions are true:—

Hot baths, like any other application of heat, soothe pain; hence they are useful for rheumatoid anthritis and colic, whether it be renal, biliary, or intestinal. By bringing blood to the skin and lessening the amount in the internal organs they relieve muscular spasm such as we find in stricture of the urethra, colic, laryngismus stridulus, other forms of laryngeal spasm, and infantile convulsions. In the same way they are of service in weariness from muscular or cerebral activity, are soporific, and are useful in many inflammatory affections, as a cold in the head. The subsequent increased perspiration makes them of great value in the various forms of nephritis and in anæmia. Great care must be taken after a hot bath which has been given to induce sweating to see that the patient is kept warm by being wrapped quickly in a hot blanket and being put into a warm bed. If not, the cutaneous vessels soon contract, all the good of the bath is undone, and there is no diaphoresis.

The same names are applied to local baths whether they are hot or cold.

We have seen that the local application of cold to a part causes contraction of the vessels and lowering of the temperature; in the same way the local warm bath causes a great dilatation of the superficial vessels of the part and a local rise of the temperature of the skin. As a result of this dilatation blood is withdrawn from distant parts, the size of the part to which the heat is applied is increased, and when the warmth is withdrawn a copious local perspiration takes place. Often as with cold so with heat, a reflex effect upon the vessels of some deep-seated organ occurs. This is due to the stimulation of the skin by the heat. For example, upon the application of warmth to the chest not only the cutaneous vessels of the chest-wall but those of the lungs and pleura immediately underneath the point of application, dilate. The local hot baths most frequently used are the foot bath, which is very often used to withdraw blood to the lower extremities in a case of cold in the nose; and the sitz bath, which leads to dilatation of the pelvic vessels and may, therefore, be used in amenorrhœa. A mustard bath is a local hot bath to which from one to three ounces of mustard have been added to every fifteen gallons of water.

The Physiological Action of the Constituents of the Bath

There has for several years been a long and heated controversy as to whether the constituents of a bath are absorbed by the skin.

Many have attempted to determine whether water was absorbed by the skin. Some weighed the bather before and after the bath, others weighed the water. Some concluded that the body gained in weight from the absorption of water, others thought it lost weight in a bath, and others again could detect no difference whatever. Observers have been even known to declare that a bath increased the weight of the bather by pounds. In all these experiments the most obvious fallacies—such as the evaporation of water, the failure to dry the bather completely, and many others—were not guarded against, and the whole of the experiments are, therefore, perfectly valueless. Krause made a series of experiments upon the power of pieces of dead skin to imbibe water, and because he found that, after a long time, it could absorb water, certain people have jumped to the conclusion that the skin absorbs water in a bath, quite forgetting the fact that Krause experimented with

pieces of dead skin. Imbibition by the skin was thought also to be proved by the fact that if the arm were placed in a vessel containing some salt in solution and then in plain water, the latter was found to contain some of the salt, but no allowance was made for the fact that some of the salt might have adhered to the hairs on the arm. Lastly, we need hardly point out that an increased flow of urine after a bath is not, as some would have us believe, any evidence whatever that water has been absorbed, for the variations in the vasomotor condition of the skin are quite enough to account for it. Therefore, we may conclude that there is no evidence that the skin can absorb water from a bath; indeed, when we remember the oily condition of the epidermis, covered as it is by sebaceous secretion, we should hardly expect that it could take up any water.

Multitudes of experiments have been made with the object of showing that any salts which are dissolved in the water are taken up by the skin. The salt most frequently used has been chloride of sodium. Beneke and Röhrig have shown most conclusively that this is not absorbed. The latter observer carefully estimated the amount of chloride of sodium excreted by a patient and then he gave a salt bath, of a temperature of 95° F., but could detect no increase in the amount of the salt in the urine.

Many experiments have been made with salts of iron; the most satisfactory are those in which ferrocyanide of potassium was used, and all these show that salts of iron are not capable of absorption by the skin. Experiments with salts of lithium likewise gave negative results. Iodide of potassium is a favourite salt for experimentation, as it is very diffusible; many experiments appear to show that this can be absorbed by the skin, but no guard has been made against the fallacy that it is very liable to be decomposed in the bath and that the free iodine thus given off, being volatile, may be taken up by the lungs. The amount that it has been supposed the skin might take up is not greater than may be accounted for in this way. Some observers have put powerful drugs, such as opium, belladonna, digitalis, corrosive sublimate, into the water, and have endeavoured, by observing whether the patient was affected by them, to determine if they were absorbed by the skin; but all these experiments were so carelessly conducted that they are valueless. If, therefore, we exclude substances which might have a powerful chemical influence on the skin, and also those which are volatile and might, therefore, be absorbed by the lungs, we see there is no evidence whatever that the skin has any power of absorbing substances which are dissolved in baths.

Chrzonsczewsky has made some experiments which are so often quoted that we must just refer to them. He shaved parts of animals and immersed the shaved parts in baths containing various substances in solution. The water of the bath was covered with oil to prevent evaporation. According to Chrzonsczewsky, large quantities were absorbed, but we are not told whether the animals were scratched or cut during the shaving, and the symptoms produced were so severe that there is clearly an error somewhere. There is no doubt that the skin can absorb small quantities of volatile bodies such as iodine, but even in these cases the amount absorbed by the lungs is probably much greater. Of course it is well known that some substances, such as mercury, can be absorbed by the skin if they are rubbed in thoroughly.

The skin appears to absorb small quantities of certain gases that are dissolved in the water of a bath, but, as just mentioned, this is probably to be entirely explained by the fact that some of the gas is given off from the bath and is taken up by the lungs and such of the skin as is not under water. Chloroform, ether, hydrocyanic acid, carbon dioxide, carbonic oxide, and sulphur dioxide are instances of gas that can be absorbed in this way. The

amount which can be taken up by the skin is so small, in comparison with the quantity that can be taken up by the lungs, that inhalation is always to be preferred to cutaneous absorption.

It has been repeatedly stated that baths with a salt or gas in them have a stimulating effect upon the skin. This is, however, very slight—so slight indeed that Leichtenstern considers that its only effect is, to a small extent, to influence the vasomotor effect of baths, so that the vascular dilatation after a cold bath, and the vascular dilatation in a warm bath, are a little increased if the bath contain a salt or gas in solution; but he goes on to say that this stimulating effect of the salt or gas is too small to influence the frequency or depth of the respiration, or to modify the quantity of urine passed after the bath, or to influence the quantity of urea and carbon dioxide excreted, or to alter the temperature of the body or the pulse-rate. In fact, the influence of the gas or salt dissolved in the water is so slight that it may be totally disregarded, and baths act chiefly by their temperature.

We have seen that no absorption takes place in a bath; nevertheless, it is probable that the superficial layers of the epidermis can to a slight extent imbibe water, although so little is thus taken up that the effects of the imbibition are inappreciable.

Leichtenstern calculates that probably 500 to 600 kilogrammes are in an ordinary bath added to the atmospheric pressure of 15,450 kilogrammes on the whole body. We, however, know nothing of any effects which can be attributed to this action.

The electrical operations of a bath are involved in much obscurity. Heymann and Krebs appear to be the most careful of those who have experimented upon this subject. They found that all the mineral and gas containing waters, with the exception of sulphur ones, act positively when brought in contact with distilled water; that the highest degree of electrical relation was caused by the presence of the gases in the water, the next degree by the temperature of the water, and the third degree by the presence of salts. The gases experimented upon were carbon dioxide, nitrogen, oxygen, and sulphuretted hydrogen. The alterations due to temperature were to be attributed to variations in the conductivity of the water. The gases contained in water (except sulphuretted hydrogen) are the cause of their electro-positive behaviour, for distilled water containing neutral or basic salts is towards plain distilled water not electro-positive but electro-negative. The only information we have upon the electrical reactions of the human body when in water is derived from an experiment of Heymann's. A man was put into a bath. One pole was placed in the bath water and the other on the man's skin outside the bath. Ordinary water, and water containing carbon dioxide, were both of them positive, while the body was negative; but if sulphuretted hydrogen was dissolved in the water this was negative and the body positive. It is not known whether these electrical variations have any effect upon the human body, nor is any use of them made in medicine. It is quite needless to refer to the large amount of rubbish that has been written on the subject of the electrical reactions of baths.

THE USES OF BATHS CONSIDERED ACCORDING TO THEIR TEMPERATURE

We will now pass on to the consideration of the uses of baths, and in so doing we shall omit many of the applications which most writers on balneology describe. There is probably no disease for which baths have not been

recommended, but frequently those who advocate some particular form of bath are pecuniarily interested in bathing-establishments, and a little examination shows that the bath cannot possibly have the beneficial effects attributed to it. The uses of special kinds of baths will be described under separate headings.

Uses of Indifferent Baths

Baths in which the bather feels neither hot nor cold are used for cleansing purposes and also for the mild exhilarating effects that the bather feels on leaving them, when he has rubbed himself quickly with a rough towel. No time should be lost between the exit from the bath and the drying, whether the bath be warm, cold, or indifferent, for the evaporation of the water from the skin will cool the body. Directly after drying, the clothes should be put on. No bath, whatever its temperature, should be taken immediately after a meal. It is said that indifferent baths will cure mild functional nervous diseases, such as slight cases of hysteria. Unfortunately, many authors apply the term 'indifferent thermal waters' to warm baths not containing any important mineral constituent.

Uses of Cool or Cold Baths

The temperature of the water which can be used for baths varies immensely for different people, but everyone can easily find for himself the temperature which suits him best. It must never be so low as to prevent the reactionary dilatation of the cutaneous vessels which ought to succeed after a bath. For the same reason a cold bath must never be prolonged. Directly upon leaving the bath the bather must rub himself thoroughly and quickly with a rough towel to aid the cutaneous vascular dilatation, and it is particularly important that, in order to prevent any loss of heat, he should dress quickly. We have already seen that after a cold bath there is a feeling of exhilaration and warmth, the energy appears to be increased and the mental faculties quickened. It is for these effects that a cold bath on getting up in the morning forms part of the daily life of so many Englishmen. Persons accustomed to cold baths are less liable to catch cold than those who do not use them. Apart from their antipyretic effect, cold baths are chiefly used for their stimulating effect. There are many hydropathic establishments with admirable cold baths, and where all the accessories, such as rest, fresh air, and regular meals, aid the hydrotherapeutic treatment. Patients suffering from general exhaustion, due mostly to mental overwork, strain and anxiety, are often conspicuously benefited by a stay at a hydropathic establishment. Very often patients of this class suffer from chronic indigestion, which is frequently alleviated by a visit to one of these places; therefore, when the two conditions are combined, such treatment is particularly suitable. Certain cases of hypochondriasis and hysteria are sometimes brilliantly cured, but in others no good whatever results. We have already indicated the principles which should guide us in the local application of cold. Cold hip baths have been found useful in impotence, spermatorrhœa, amenorrhœa, and prostatitis. The cold douche is largely used as a local stimulant, and will reflexly affect the circulation in the organs under the point of application.

The places best known for their cold baths are Ilkley, Ben Rhydding, Malvern, Wemyss Bay, Forres, Crieff, Nassau, Boppard, Godesberg, Wiesbaden, Alexandersbad, Liebenstein, and Rigi Kaltbad.

The Antipyretic Uses of the Cold Bath.—The use of the cold bath in fever has, during the last twenty-five years, revolutionised our ideas concerning the treatment of febrile disorders. It is a very wide subject, and therefore in an article of this nature only a brief account of it can be given. Fuller information may be found in Liebermeister's 'Antipyretics;' Von Ziemssen's 'Handbook of General Therapeutics,' vol. ii. Eng. Trans. 1885–6; Currie's 'Medical Reports on the Effects of Water, Cold and Warm, as a Remedy in Fever and Febrile Disorders when applied to the Surface of the Body or used internally,' 4th edit. London, 1805; Tripier and Bouveret's 'La Fièvre typhoïde traitée par les Bains froids,' Paris, 1886; Fismer, 'Kaltwasserbehandlung bei der acuten Croupösen Pneumonie,' *Deutsch. Arch. f. Klin. Med.* 1873; and the writer's 'Text-book of General Therapeutics,' London, 1889. From the latter the following account is chiefly abstracted.

The first person to put the treatment of fevers by cold water upon a scientific basis was Currie, the first edition of whose work appeared in 1797. The great merit of Currie's work over that of his predecessors is that he took the temperature of his patients. Giannini in 1805 gave an account of the employment of cold for fever. The use of this method, however, died out, until it was again brought under the notice of the profession by Brand in 1861, and since then many authors have discussed the subject.

In considering the action of a cold bath in fever we have to remember that the thermic mechanism of the body consists of three parts: (1) a thermogenetic, by means of which heat is produced by changes going on chiefly in the muscles which are the main thermogenetic organs of the body; this function is presided over by the central nervous system, probably that part of it which is in the neighbourhood of the great basal ganglia. (2) A thermolytic mechanism which presides over the loss of heat. Its chief parts are the cutaneous vasomotor system and the sweat-glands. It is likewise under the control of the central nervous system. Heat is lost from the skin by conduction, radiation, and evaporation. (3) Lastly, there is a thermotaxic mechanism whose function is to maintain the balance between the thermogenetic and the thermolytic. This mechanism must clearly be nervous. In fever the production of heat is enormously increased. Those pathologists who believe in the value of antipyretic methods of treatment assume that the pyrexia of fever is harmful, and that by diminishing it we benefit the patient.

From the above it is seen that the possible modes of action of a cold bath are very numerous. It is clear that a cold bath must directly abstract heat. Maclister has shown that cold diminishes the thermogenetic activity of muscle, and it is almost certain that a cold bath acts in this way, especially if the cutaneous vessels are dilated, as they often are in fever, for then cold blood is quickly carried to the muscles. It is true that when a fever patient is put into a cold bath the rectal temperature at first rises a little. This is soon succeeded by a fall, and it may be explained either by the fact that the water interferes with the loss of heat by evaporation and radiation, or that there is at first a slight, temporarily increased thermogenesis which is an abortive attempt to compensate for the direct abstraction of heat by the cold water. After the patient has been taken out of the bath, the temperature continues to fall, probably because for a short time the activity of thermogenesis remains depressed. There are many ways of employing cold to reduce fever. Simple sponging with cold water calls for no description.

The Cold Bath.—This is undoubtedly the most efficacious. It is best applied by means of a long bath placed at the end of the bed, so that both are in the same straight line. The patient with a blanket over him is lifted in a sheet, and by it lowered into the water while the blanket remains over the top of the bath. To lift him out, several persons place their hands under him and the wet sheet is left behind; he is put back into bed and a sheet or simple blanket is thrown lightly over him. The temperature of the bath should be between 58° and 68° F. or warmer, if that of the patient be high. The point of fever heat at which he should be bathed varies with the disease. The immersion should last about ten minutes, for the quantity of heat which at the end of this time can be further abstracted is small, as the rapidity with which heat is given from a hot body to a cold one increases with the difference of temperature between the two. Hence short bathings frequently repeated are much more potent than long ones. The temperature of the bath may be higher in children, for they present a much greater proportional surface from which to withdraw heat. In private practice there is sometimes much inconvenience in arranging the bath. This difficulty may be surmounted by raising the head of the bedstead a few inches and thereby making an inclined plane of it. Under the patient a large macintosh sheet is placed and it is extended over a bank of pillows on either side, a gutter is made in the macintosh at the foot of the bed so that cold water poured in at the head will run out at the foot, where it is caught in some suitable vessel. The pillows at the side may be so high that the patient lies in a stream of running water.

The Tepid Bath gradually cooled.—This, first employed by Ziemssen, is applied thus: The patient is put into a bath the temperature of which is from 9° to 10° F. below that of his body. Cold water is then gradually poured in till, after ten or fifteen minutes, the temperature of the bath has fallen to about 68° F. He remains in from twenty to thirty minutes, when generally severe shivering or chattering of the teeth begins. He is then quickly moved back to a bed which has been previously warmed. This method is not nearly so potent as the cold bath, and is more difficult to carry out; nevertheless it has two great advantages—namely, that it is more comfortable to the patient; and that it can be used for cases in which, from the condition of the heart, there is any likelihood that the shock of the cold may be too severe.

The Cold Affusion.—This is the method Currie used, for he threw cold sea-water over those whom he treated. The patient should be placed in an empty bath, and water at about 60° F. thrown over him; this is done for about five minutes. The cold affusion is now but rarely used, for the reduction of temperature caused by it is but slight, and the shock is so great as to be extremely disagreeable. It is absolutely forbidden when there is any sign of cardiac mischief. Possibly some of Currie's good results may be set down to the fact that he used salt water, which is more stimulating than fresh.

The Cold Pack.—The naked patient is wrapped in a sheet, four folds thick, which has been wrung out in cold water, and is carefully placed between the thighs and axillæ. It is often recommended that the sheet should not quite reach to the feet, because of the difficulty of throwing it over them. Outside it a blanket is thrown. In five or ten minutes the patient is removed from between the folds of the sheet and a fresh one is substituted. This is more easy if there are two beds. The process is repeated four or eight times, and even then is not so powerful as a cold bath.

Ziemssen and Immerman give the proportionate efficacy of the cold affusion,

a series of four cold packings, the gradually cooled bath and the cold bath, at 1 : 2 : 3 : 4. Cold baths administered to febrile patients in the latter part of the evening and in the night cause a more durable and a greater reduction of the temperature than those given in the daytime, and the reduction produced by a nocturnal cold bath is greater than would be the difference between night and day temperatures in the same case if it had not been treated by a cold bath. This is due no doubt in part at least to the fact that at night the temperature is naturally falling, and that it is easier to reduce a falling temperature than a rising one. We thus learn that baths ought to be continued through the night.

We will now briefly consider some of the diseases for which the cold bath treatment has been employed.

Typhoid Fever.—The cold bath has been very much used for this disease, and in many institutions it was the routine practice. Numerous statistics have been published, and they all show that the mortality from typhoid fever since the introduction of the cold bath is much less than it was before. Murchison calculates that the mortality of typhoid fever when treated on the expectant plan is 17·45 per cent., and Jaccoud says it is 19·23. Brand puts the mortality after the introduction of the cold bath treatment at 6 per cent. If we contrast the treatment at the same hospital before and after the introduction of the cold bath we find the contrast very distinct. Liebermeister's statistics show that at Basle from 1854 to 1864 mortality under the expectant symptomatic treatment was 18·1 per cent. The mortality in subsequent years among those who were treated by the cold bath was 11·2 per cent., and many other statistics might be quoted all showing a great fall in the death-rate. In Germany it is usual to fix the temperature at which a bath should be given at 102°·2 F. Many place it at 103° F. In order to get the best results possible the case must be consistently treated from the beginning.

Fever patients come under treatment more frequently late than early, yet among twenty patients whose deaths are recorded by Tripier and Bouveret, in seven the treatment had been begun after the twentieth day, in ten between the eighth and sixteenth days, and in three only during the first week. One can never say what course a case of typhoid fever will take, and therefore it is very important to begin the treatment early, even if the case appear to be mild.

It might be thought that cold bathing would increase the frequency of complications, especially bronchitis and pneumonia; but this is not the case. Hoffmann and Liebermeister estimate that, while the complications from severe lung mischief among those treated on the expectant method was 20 per cent., among those treated by cold baths it is only 7·7 per cent.

Experience has shown that epistaxis, pleurisy, and albuminuria are not contraindications to the treatment. Of course perforation of the intestine and peritonitis are absolute contraindications to treatment by cold baths, and so is intestinal hæmorrhage, if it be severe, but not if it be mild. If the patient suffers from severe heart disease, or if he is very collapsed when first seen, a cold bath should not be given. Pregnancy, menstruation, phthisis, bronchitis, obesity and old age are not in themselves contraindications.

Cold baths not only reduce the temperature; they also benefit the patient in other ways. At first the contact with the cold is very disagreeable, but after a short time he feels much more comfortable, the pulse and respirations fall in frequency, and often delirium disappears, and all those symptoms which make up the typhoid condition are ameliorated.

The application of cold does not shorten the fever, it only diminishes its intensity. Relapses are said to be more frequent after the administration of

the cold bath than they are if the patient is treated without them, but the difference is so slight as to be of no practical consequence. It is probable that ultimately some of the newly introduced antipyretic drugs, such as antifebrin, will, to a large extent, replace the use of the cold bath for typhoid fever.

Typhus Fever.—This was the malady for which Currie principally used the cold-water treatment. Jürgensen and Brand have also used it with good results.

Pneumonia.—Of late years the treatment of pneumonia by cold water, externally applied, has come much into vogue, especially in Germany. Liebermeister states that by it the mortality from this disease in the hospital at Basle has been reduced from 25·3 to 16·3 per cent. Fismer contrasts 230 cases treated before the introduction of the cold bath with the same number treated by it, and finds the deaths to be sixty in the first series, as against thirty-eight in the second. He fixes the temperature at which the bath should be given at 102°·2 F. It does not appear that the disease is curtailed by it.

Rheumatic Fever.—The majority of cases of this disease are so adequately treated by compounds of salicylic acid, or by the acid itself, that they do not require to be treated by cold baths; but the case is different with rheumatic hyperpyrexia. Here the temperature rises so rapidly that most energetic means must be adopted the moment there are any symptoms of the onset of hyperpyrexia; by this means the most desperate cases can be saved. The Clinical Society appointed a committee to investigate the subject, and they reported that out of the cases which were not bathed only one, in which the maximum temperature exceeded 106, recovered; but of the cases which were bathed fifteen, or five-eighths of the total in which the maximum exceeded 106, recovered. In six out of eleven fatal cases which were not bathed, the maximum was under 106; but in only three out of twenty-two fatal bathed cases was it so low. A perusal of the report of the committee will show that energetic cold water bathing is most necessary in all cases of rheumatic hyperpyrexia.

Cold-water bathing has been employed for almost every disease accompanied by a rise of temperature. Thus it has been used for scarlet fever, small-pox, measles, pleurisy, meningitis, and erysipelas.

Uses of Warm Baths

These are most used for washing, and for that purpose are far more efficacious than cold, because they aid the removal of the fatty secretions of the skin.

Their uses need not occupy us long, for they have been already indicated in the account given of the physiological action of warm baths. They are used for two main purposes, dilatation of the cutaneous vessels, and the soothing of pain.

Dilatation of cutaneous vessels is required whenever we wish to abstract blood from internal parts. Thus a warm bath promotes sleep if taken immediately before going to bed, as it withdraws blood from the brain; but it is, of course, essential that the patient should go to bed immediately after the bath and be thoroughly wrapped up so that the dilatation may be maintained. General weariness is relieved by a hot bath, because it withdraws blood from internal organs and thus rests them. A hot bath is a favourite remedy for a cold and other mild inflammatory disorders, for the reason that the blood is diverted from the inflamed part to the skin; here, also, it is important

that the patient should after the bath at once go to bed and be wrapped in blankets to maintain the dilatation. Warm baths are largely used for the diaphoresis which occurs after them; for this reason they are employed in Bright's disease. In this malady, as it is very desirable to maintain the heat for some time, a hot pack or hot-air bath is often to be preferred to a hot-water bath. To maintain the diaphoresis after any of these the patient should be well wrapped in hot blankets.

Warm water is largely used to relieve pain and muscular spasm, as we see in its application for renal, intestinal, and biliary colic, and also in the fact that a catheter can often be passed successfully in a warm bath, when previously all attempts had failed. A warm bath is a very frequent remedy in infantile convulsions. Certain skin diseases in which there is a large accumulation of scales, such as psoriasis, very chronic eczema, and exfoliative dermatitis are improved by warm baths. For these maladies Hebra so arranges a bath that a patient can remain in it for days at a time, without getting out to relieve either the bowels or the bladder. The water is pleasantly warm and is kept at a constant temperature. Tepid baths allay irritation, and are, therefore, of use for the itching of prurigo, the tingling of erythema, and the itching of jaundice. Dujardin-Beaumetz recommends them for use during the eruptive stage of small-pox. For the above purposes they are generally employed at the patient's own house, but there are a large number of bathing-places whose reputation rests solely upon their warm baths. They are chiefly used for chronic rheumatoid arthritis, and to absorb chronic inflammatory products. Leichtenstern says: 'It is a matter proved by multiplied observation that the products and residue of chronic inflammation and hyperplexia of tissue can be favourably influenced by the use of warm baths. The old and deserved reputation of thermal springs in the treatment of chronic rheumatism of joints and muscles, of rheumatic contraction and false ankylosis, of the effects of past attacks of gout, can hold its own even against the extreme of scepticism. The methodic use of thermal waters often improves and cures certain chronic skin affections, ulcerous processes of the skin, badly granulating torpid wounds, fistulas and caries of bone, cicatrices distorting the skin, muscle, sinew and joint exudations that remain behind after luxations, fractures, and gunshot wounds, and which often interfere so much with the function of the parts affected. Chronic exudations also after pleurisy, pelvic peritonitis, perityphlitis, peri- and parametritis may at times be ameliorated by warm baths. Undoubtedly certain affections of the nervous system are suitable for the employment of thermal baths, for they are often appropriately employed in various forms of old stationary cerebral, spinal, peripheral and taxic paralyses; further, in various neuralgias and hyperæsthesias, in some forms of hysteria, neurasthenia, and hypochondria' (Leichtenstern; Ziemssen's 'Handbook of General Therapeutics').

The following is a list of the more important places which are celebrated for their warm springs. The figures indicate the temperature in degrees Fahrenheit:—

Aix-les-Bains (90–114); Badenweiler (79–100); Baden (114–120); Bath (107–117); Bormio (95–104); Brussa (55–170); Buxton (82); Dax (116–140); Gastein (95–138); Hammam-Mescontin (115–203); Hammam-R'Hira (107–110); Leukerbad (102–124); Néris (118–125); Pistyan (86–104); Plombières (66–158); Pfaffers (104); Ponte Seraglio (100–129); Ragatz (96); Römerbad (93–99); Schlangenbad (80–89); Teplitz (105–118); Warmbrunn (96–107); Wildbad (93–102).

The innumerable local uses for warmth hardly fall within the scope of this article. Hot sitz baths have already been mentioned.

USES OF BATHS CONSIDERED ACCORDING TO THEIR CONSTITUENTS

In this place we will only consider natural baths, and they are quickly dismissed, for, as has already been pointed out (p. 627), there is no evidence whatever that substances dissolved in water to such a slight extent as they are found in natural waters have any effect whatever. All the good that patients profess to obtain from such baths is to be attributed either to the temperature of the water or to the accessories, such as fresh air and good diet, which are met with at the bathing establishments. For example, in olden days the most marvellous effects were attributed to sulphur baths, but it is interesting to note that at the most celebrated places possessing sulphur baths the water was warm and the diseases for which sulphur baths were recommended were just such as would be benefited by warm baths. The consideration of the constituents of the bath naturally leads us to sea-bathing.

SEA BATHS

The following table will show that these fall under the heading of cold baths. The mean summer temperatures of the sea are :—

	Degrees Fahrenheit
Mediterranean	71·6 to 80·6
Atlantic (European)	68 „ 73·4
German Ocean	60·8 „ 64·4
Baltic Sea	59 „ 62·6

The following table of the composition of ocean water shows that chloride of sodium is the only important constituent :—

Chloride of sodium	25·1
Chloride of potassium	·5
Chloride of magnesium	3·5
Sulphate of magnesium	5·78
Sulphate of lime	·15
Carbonate of magnesium	·18
Carbonate of lime	·02
Carbonate of potassium	·23
Iodides and bromides	traces
Organic matter	traces
Water	964·54
Total	1000·00

The composition of sea water in various parts of the world is as follows, the quantity of salts being expressed in parts by weight in 1,000 :—

Dead Sea	227·69
Mediterranean at Marseilles	40·7
South Atlantic	36·4
North Atlantic	35·97
Pacific	34
Indian Ocean	33·86
English Channel	32·35
German Ocean	29·0
Black Sea	15·9
Baltic	5 to 9

We have, therefore, to deal with a cool bath consisting of a strong solution of common salt. To avail himself of the bath the patient must live at the sea-side, and it must be taken in the open air and its water be constantly moving.

We have already seen that a cool bath is a stimulant, that it produces a feeling of exhilaration and strength, that the faculties are quickened, and that, within certain limits, it conduces to maintaining a healthy condition. All the virtues of an ordinary cool bath are intensified in a sea bath by the motion of the water, and it is probable that the salt itself has some slight stimulating effect; but this is but small in comparison with the advantages derived from the temperature of the water and its movement. The sea air is, no doubt, a powerful factor in aiding the robust health often attained by persons living in towns when they come to the sea-side for sea-bathing.

It is difficult to name any diseases which are specially benefited by sea-bathing. It helps to maintain the health of the healthy, and it is particularly serviceable in restoring to health those who are pale, anæmic, and wasted, and those who are convalescent from any serious disease. Those weak, sickly, sallow creatures so often seen among the poorer inhabitants of towns are usually regenerated by a course of sea-bathing. They regain their colour, they put on flesh, and their strength is restored. Those who are usually said to be scrofulous are much benefited by sea-bathing.

Weakly individuals should only take one sea-bath a day. It should always be before 1 P.M., and is best taken about two hours after breakfast. The bather should not stay in the water more than five minutes, if he cannot swim, and not more than ten minutes if he can. He should dry and dress quickly on leaving the water. Before breakfast is a good time for the healthy to bathe, and immediately after a meal is a bad time for anyone to take any sort of bath. If the bather is overheated from exertion, a sea bath, or, in fact, any kind of bath, should be taken at once, if it be taken at all, before the body begins to cool.

Turkish Bath

There may be found in Lane's 'Modern Egyptians' a very good account of a Turkish bath as it is used in Eastern countries, which shows that it is pretty much the same as our Turkish bath. Therefore I shall only mention briefly the points in connection with an ordinary Turkish bath.

The bather is, first of all, required to take off his boots, and he is then shown into the first room, which is a large room with couches and chairs placed all round it, and usually with a fountain of water in the centre. The temperature of this room is generally about 60° F., and it is, in the best baths, tastefully decorated. Here the bather undresses and wraps a cloth round his loins. He then goes to the first hot room, the temperature of which is 110–120° F., and here he sits or lies for some time. This room is tiled or made of marble, and, if the bather lie down, he lies on a marble couch with a small pillow under his head. He stays here for about half an hour whiling away the time talking and reading, during which some take a glass of water or lemonade to drink. After he has been a little while in this room he usually begins to sweat profusely. The next room to which he goes is the same in structure as the first hot room. Its temperature is higher, usually about 150° degrees. Here the bather remains for a shorter time than in the first hot room, and during his stay he sweats still more. He may proceed to other hotter rooms, the number and temperature of which vary at different baths. In some there are three more, the temperature of the hottest being

from 250° to 300° F. When the bather has left the hotter rooms he goes back to the first hot room, where he is thoroughly kneaded and shampooed all over. The shampooer massages all the muscles and rapidly moves the chief joints. The arms are usually first done, then the legs, and lastly the trunk. This being finished, the bather goes to the washing-room, where he is lathered all over, and the lather is washed off with warm or cold water which is thrown over him. Some then take a cold plunge bath, while others prefer a cold douche. The next stage is to return to the dressing-room, where the body is lightly dried and the bather sits, well wrapped up in a large towel, for half an hour or so, during which time he can smoke and drink a cup of coffee. He then dresses and the bath is over. This is the usual course of the proceeding, but there are many variations. Sometimes a cold douche is taken immediately upon entering the first hot room, sometimes the hot rooms are taken in a different order to that mentioned above, the most usual variation being that the bather goes first into the hottest room and then gradually passes through the others.

The most obvious effect of the hot air is that it produces a great increase in the perspiration, which literally runs down the body. There is, at the same time, considerable hyperæmia of the skin. The sweat evaporates very fast and, therefore, the temperature of the body does not rise as much as it otherwise would, and it is also kept down by the evaporation of the pulmonary aqueous vapour. Those who drink plenty of water naturally sweat more than those who do not. Some before going into the hot rooms contract the cutaneous vessels by throwing cold water over themselves. The respiration and pulse are both quickened and there is some loss of weight. Many persons complain considerably of cardiac palpitation in the hottest rooms. The following table, compiled from Frey and Heiligenthal's 'Luft- und Dampfbäder,' shows some of the effects of a Turkish bath :—

Condition before the bath :—
Weight, 66,150 grammes; pulse, 72; respiration, 15; axillary temperature, 36°·9 C.; rectal temperature, 37°·7 C.
In a room at a temperature of 50° C.
At the end of 10 minutes :—
Pulse, 94; respiration, 17; axillary temperature, 37°·1 C.; rectal temperature, 37°·7 C.
At the end of 15 minutes the sweating began.
At the end of 20 minutes :—
Pulse, 104; respiration, 18; axillary temperature, 37°·5 C.; rectal temperature, 37°·8 C.
At the end of 30 minutes :—
Pulse, 104; respiration, 18; axillary temperature, 37°·7 C.; rectal temperature, 37°·9 C.
The patient then went to a room at 65° C.
At the end of 5 minutes :—
Pulse, 110; respiration, 19; axillary temperature, 38° C.; rectal temperature, 38° C.
At the end of 10 minutes there was very profuse sweating.
At the end of 15 minutes :—
Pulse, 120; respiration, 19; axillary temperature, 38°·5 C.; rectal temperature, 38°·3 C.
At the end of 20 minutes there was considerable discomfort :—
Pulse, 125; respiration, 20; axillary temperature, 38°·7 C.; rectal temperature, 38°·4 C.
The patient then went to rest in the cooling-room.
At the end of 5 minutes :—
Pulse, 95; respiration, 15; axillary temperature, 36°·0 C.; rectal temperature, 37°·7 C.

At the end of 10 minutes:—

Pulse, 80; respiration, 15; axillary temperature, 36°·7 C.; rectal temperature, 37°·7 C.

At the end of 20 minutes:—

Pulse, 72; respiration, 15; axillary temperature, 36°·8 C.; rectal temperature, 37°·7 C.

Weight of the body after the bath, 65,190 grammes.

Loss of weight in the bath, 960 grammes.

The urine for the whole of three days before the bath was bright yellow. Its daily averages were that 1,567 cubic centimetres were passed, which gave 25·7 cubic centimetres to each kilogramme of body-weight. The specific gravity was 1018·8. The urea was 45·47 grammes, which gave 0·688 to each kilogramme of body-weight. The uric acid was 0·633 gramme, which gave ·009 gramme to each kilogramme of body-weight.

The urine for the whole day of the bath was red, clear, without sediment, and strongly acid: 950 cubic centimetres were passed, which gave 14·5 cubic centimetres to each kilogramme of body-weight. The specific gravity was 1027. The urea was 39·90 grammes, which gave ·604 to each kilogramme of body-weight. The uric acid was ·860 gramme, which gave ·013 to each kilogramme of the body-weight.

The authors give other experiments, but as the above is a typical one there is no need to refer to others. It shows us very well the rise in the pulse, respirations, and temperature in the bath, and also that soon after its cessation these have returned to normal. There is some difference of opinion about the alteration in the amount of urea. According to Bartels and Naunyn, the excretion of it is slightly increased, but the careful experiments of Frey and Heiligenthal show that this is not so during the bath, for it decreased from 45·47 grammes as a daily average before the bath to 39·9 grammes during the day of the bath. Their experiments seem so careful that we may probably conclude that they show the effect of a Turkish bath is to make the urine dark in colour, strongly acid, scanty, of a high specific gravity, with a diminution in the quantity of urea and an increase in the quantity of uric acid. These experimenters, however, go on to say that some time after the commencement of a series of baths, even as late as the second day, there is a slight increase in the amount of urea passed, and more uric, phosphoric, and sulphuric acids are excreted so long as the baths continue. It will be noticed how soon after the bath the pulse respiration and temperature returned to normal, and also that there was a considerable loss of body-weight. Manensein gives the limit as from a quarter of a pound to two pounds, but the writer has known a man lose five pounds in a bath of an hour and a half's duration.

Oertel has made a series of experiments, with the object of determining the relative value of the various means we possess of producing diaphoresis. They are not altogether satisfactory, for it is a very difficult matter to compare things so different and to have similar conditions of experiment in each case. He, however, comes to the conclusion that mountain climbing is by far the most powerful means that we possess of increasing the excretion of water by the skin and lungs, and that the next most potent, but more uncertain, method is the subcutaneous injection of pilocarpine, then a Turkish bath, and last of all in its efficacy comes a vapour bath.

Bearing in mind what we have said about the physiological action of the hot-air bath, it is not difficult to see its uses. In the first place, it is, owing to the rubbing of the skin, thoroughly cleansing; any excess of fatty matter is rubbed off, so that subsequently the bather's skin is in a much more healthy condition than it was previously. The shampooing and massage cause a feeling of comfort and strength after a bath. The alteration in the condition of the urine, such as the increase of uric acid, the primary diminution and subsequent increase of urea, the loss of body-weight, the large amount of

perspiration, all show that Turkish baths must modify the metabolism of the body, and must also be powerful excretory agents. These circumstances probably explain the fact that they are of great use in aiding the absorption of old inflammatory products, such as those due to syphilis, chronic rheumatism, rheumatic myalgia, and gout. Massage alone is useful in these affections, but still more is the Turkish bath valuable, for it combines massage with other aids to absorption. For the same reason those who have been chronically poisoned by lead or mercury usually derive benefit from a course of Turkish baths. Sciatica and neuralgia are also among the diseases for which they are to be advised, for all the factors of a Turkish bath will aid recovery. The profuse diaphoresis renders them valuable for those suffering from the chronic uræmia of chronic Bright's disease, and Frey and Heiligenthal do not forbid them in these cases, even if the heart is hypertrophied, provided that there are no other contraindications. The fact that they cause a loss of weight has led to their being largely used by the corpulent. No doubt they are of use to those who have not sufficient strength of mind to diet themselves, but dietetic treatment for obesity is much more valuable than a course of Turkish baths. If care be taken not to get a chill on leaving the bath, a Turkish bath will often cure a cold in the head, and patients suffering from slight bronchitis with abundant expectoration find themselves alleviated by one.

They should be absolutely forbidden to those who have valvular disease of the heart or aneurysm, and must be taken with great care by the very old and by those in whom there is any reason to suspect a fatty heart.

Local hot-air baths are chiefly used as a means of producing diaphoresis in Bright's disease. A cradle is put over the patient while he is in bed, over this the bed clothes are thrown, and under the cradle a lamp is placed. The clothes are so arranged as to prevent the exit of the hot air, and such parts of the patient as are under the cradle are soon heated to such a heat that profuse perspiration results. This method is very efficacious and is commonly used. It is not, however, quite so much in vogue since the introduction of pilocarpine.

A form of Turkish bath which the patient can use in his own house is sold. It consists of an apparatus so arranged that when he is sitting on a chair a large cloth, which is fastened tightly round the neck, falls down over the chair to the ground, so that the whole of the patient except the head is contained in it. A lamp is placed under the chair and the cloth is securely fastened, so that no air has access from the outside. The air inside becomes very hot and profuse diaphoresis takes place. This form of bath is not nearly so comfortable as an ordinary Turkish bath, and has the great disadvantage that it is not possible to easily regulate the temperature in it.

Hot Vapour or Russian Bath

This form of bath is rarely used by the English, but it is met with in many foreign cities and bathing establishments. As probably many of my readers are unacquainted with it, I quote the following description of a Russian bath from Kohl's 'Russia:'—The passage from the door is divided into two behind the checktaker's post, one for the male, one for the female guests. We first enter an open space, in which a set of men are sitting in a state of nudity on benches, those who have already bathed dressing, while those who are waiting to undergo the process take off their clothes. Round this space or apartment are the doors leading to the vapour rooms. The bather is ushered into them and finds himself in a room full of vapour, which is sur-

rounded by a wooden platform rising in steps to near the roof of the room. The bather is made to lie down on one of the lower benches and gradually to ascend to the higher and hotter ones. The first sensation on entering the room amounts almost to a feeling of suffocation. After you have been subjected for some time to a temperature which may rise to 145° F. the perspiration reaches its full activity and the sensation is very pleasant. The bath attendants come and flog you with birchen twigs, cover you with a lather of soap, afterwards rub it off, and then hold over you a jet of ice-cold water. The shock is great, but is followed by a pleasant feeling of great comfort and of alleviation of any rheumatic pains you may have had. In regular establishments you go after this and lie down on a bed for a time before issuing forth. But the Russians often dress in the open air, and instead of using a jet of ice-cold water go and roll themselves in the snow.

The physiological effects of such a bath are much the same as those of Turkish baths, and the differences will easily be gathered when we remember that, owing to the saturation of the air of the chamber with moisture, the sweat cannot evaporate. Thus high temperatures that are comfortably endured in a Turkish bath cannot be borne in a Russian bath. The temperature of the bather, however, tends to rise much more rapidly in the vapour bath than in the dry-air bath. To give an instance, Bartels has seen the temperature of the rectum of a man of 51 kilogrammes in a vapour bath of 127°·4 F. rise in ten minutes from 100°·4 to 104°·5 F. In a vapour bath of 128°·8 F. the temperature of the same individual rose from 100°·4 in eight minutes to 103°, and in thirty minutes to 107°. The pulse and respiration are increased in frequency, as indeed they always are by any form of hot bath.

Frey and Heiligenthal have carried out a series of experiments with the hot-vapour bath, and as an example we will quote those performed upon the same patient as were those quoted in the description of the Turkish bath. After three days of the daily administration of a Turkish bath, there were three days during which no bath was taken, then there were three days during which a Russian bath was taken daily. The air was saturated with vapour and the temperature of the bath was 113° F. The averages of the urine for the three days preceding the bath were 1,683 c.c., or 25·5 c.c. to each kilogramme of body-weight. The specific gravity was 1,021. The urea was 52·68 grammes, or ·783 gramme per kilogramme of the body-weight. The uric acid was ·858 gramme, or ·013 gramme to each kilogramme of body-weight.

Before the bath :—

Weight of body, 65,800 grammes; pulse, 72.

Respiration, 17; axillary temperature, 36°·9 C.; rectal temperature, 37°·7 C.

After five minutes in the vapour room :—

Pulse, 94; respiration, 19; axillary temperature, 37°·1 C.; rectal temperature, 37°·7 C.

After 10 minutes in the vapour room :—

Pulse, 110; respiration, 20; axillary temperature, 38° C.; rectal temperature, 37°·8 C.

After 20 minutes in the vapour room :—

Pulse, 128; respiration, 22; axillary temperature, 39°·2 C.; rectal temperature, 38°·0 C.

After 25 minutes in the vapour room :—

Pulse, 136; respiration, 23; axillary temperature, 39·6° C.; rectal temperature, 38°·8 C.

The patient then left the bath and went into the cooling room.

After five minutes in the cooling room :—

Pulse, 74; respiration, 17; axillary temperature, 36° C.; rectal temperature, 37°·9 C.

After 15 minutes in the cooling room:—

Pulse, 70; respiration, 17; axillary temperature, 36°·7 C.; rectal temperature, 37°·7 C.

After 30 minutes in the cooling room:—

Pulse, 70; respiration, 17; axillary temperature, 36°·8 C.; rectal temperature, 37°·6 C.

Weight of body after the bath, 65,000 grammes.

Loss of weight in the bath, 800 grammes.

Urine for the whole day red, clear, and very acid, 900 cubic centimetres, or 13·8 cubic centimetres to each kilogramme of body-weight. Specific gravity, 1027. Urea, 38·7 grammes, or ·586 gramme per kilogramme of body-weight. Uric acid, ·980 gramme, or ·015 gramme per kilogramme of body-weight.

This experiment shows us the rise of pulse, respiration, and temperature, the diminution in the quantity of the urine, its higher specific gravity, the diminution of the urea and the increase of the uric acid, and the loss of body-weight. The pulse and temperature soon sank to a little below what they were before the bath, and the respiration to exactly the same as it was before the bath. During the two days immediately after the bath the urine regained the condition it had before the bath, except that the excretion of urea was decidedly greater than it was before the bath.

The Russian bath is not so valuable in the treatment of disease as the Turkish. The warmth, the stimulus of the shock of the cold water or snow, and the stimulus of heating the body renders it useful for chronic rheumatism and for the pain of neuralgia or sciatica. Also the warm moist air renders it serviceable for such forms of dry bronchitis as require a moist exhalation. As the sweating is not so abundant as in a hot-air bath, vapour baths will not be so valuable to eliminate poisons from the system, nor so useful for the chronic uræmia of chronic Bright's disease.

Local hot-vapour baths, rigged up like a local hot-air bath, are sometimes used. A cradle is put over the patient and clothes over it. A steam kettle is placed at the end of the bed and vapour is driven into the space under the cradle.

Frey and Heiligenthal thus contrast the hot-air and the vapour bath. In both the common sensibility of the skin and the sense of appreciating between hot and cold objects are raised. In the Russian bath the capability of the muscles to respond to faradic stimuli is increased, but their strength as measured with the dynamometer is diminished. In the Turkish bath there are no alterations in these respects, but with both forms of bath there is after them a general feeling of well-being and strength. Momentarily on entering each there is a contraction of the cutaneous capillaries with a consequent hard pulse and rise of blood pressure; but immediately afterwards, owing to the dilatation of the cutaneous capillaries, the blood pressure sinks, the pulse rises, and the force of the cardiac contractions decreases. During the stay in the hot room there is anæmia of the internal organs, but hyperæmia of them after the cold douche. The respirations are increased in frequency and the temperature rises. There is much sweating in the Turkish and less in the Russian bath. In both the urine is decreased, and of high specific gravity. At first the excretion of urea is decreased, afterwards it is increased. The uric acid is increased.

Other Forms of Artificial Baths

There is hardly any limit to the many varieties of artificial baths. The following have at various times been used: Moor, peat, mud, and slime baths, pine-leaf and various aromatic herb baths, such as hay, gentian, camomile,

juniper, and marjoram baths. Brine baths and sand baths have been used, and the latter are now very popular. Among the follies of medicine are tan, bran, malt, glue, soup, milk, whey, flesh extract, blood, fermented wine, horse dung, guano, oak bark, starch, soap, corrosive sublimate, mineral acid, chloride of calcium, iron, and sulphur baths. At some bathing establishments carbonic acid gas baths are to be found, and at the present time much attention is paid to baths of compressed and rarefied air. It is obviously unnecessary to describe all these, but a short description will be given of the more popular.

Sand Baths.—The sand is dry and is evenly heated throughout to between 116° and 125° F. The lower extremities are covered in it for a depth of five or six inches, the abdomen and thorax for half an inch. The cutaneous capillaries dilate, and a profuse perspiration breaks out. The sweat cannot evaporate easily because of the sand, consequently the bodily temperature soon rises considerably. The sand and sweat form a coating to the body which has after the bath to be washed off. These baths are useful whenever warmth and heat are required, and therefore they are used for chronic rheumatism, chronic gout, and chronic Bright's disease.

Moor, Peat, Mud, and Slime Baths.—Some years ago these were extremely fashionable. They are made by mixing moor earth, peat, mud, or slime with water till the specific gravity of the mixture is about 1·2 or 1·3. The slime used is the deposit of organic matter found in rivers. They are always used warm, and any value that they may have depends not upon their constituents but upon their temperature. Plain warm water would do equally well. As an instance of the effect of a mud bath we may quote one of Kisch's experiments in which he found that a mud bath, the temperature of which varied between 100° and 104° F., quickened the pulse eight or ten beats, but in the course of two hours it became normal. The respirations were quickened and the axillary temperature was raised about 3° F. These baths are chiefly used for chronic rheumatism.

Pine Leaf Baths.—To make these, a distillate and decoction made from the leaves of pine trees is added to water, but there is no evidence that it is of any value. Probably the efficacy of these baths depends entirely upon the temperature at which they are taken.

Brine Baths.—A brine bath should contain 2 to 3 per cent. of common salt, that is, about 18 to 27 lb. to every hundred gallons of water. These baths act in the same way as ordinary salt water.

Mustard Baths are prepared by adding $\frac{1}{2}$ to $1\frac{1}{2}$ lb. of mustard to every 100 gallons of hot water. It is usually added to a local bath used to the feet for the cure of a cold in the head.

Compressed-Air Bath

This consists of a strong metal chamber circular in shape and quite air-tight. It is generally comfortably furnished with chairs and a table. When the patient is in it, air can be pumped in till the pressure is raised to the desired point. A full description of such a bath will be found in the 'British Medical Journal' for April 18, 1885, by Dr. C. T. Williams. There is one at the Brompton Hospital in London, one at Ilkley, one at Ben Rhydding, and there are several on the Continent.

An increase of pressure of $\frac{2}{5}$ to $\frac{2}{3}$ of an atmosphere is usually employed. Anything beyond this is unnecessary, and is liable to produce disagreeable symptoms. The patient at first experiences noises in the ears and a sense of obstruction and pain in the tympanic cavity. These symptoms are due to the fact that the air can pass much more easily along the external auditory

meatus than up the Eustachian tube, and consequently the membrana tympani is bulged inwards. If the patient swallow frequently they soon pass off, but only to return again when he comes out of the pneumatic chamber. General sensibility and the senses of smell, taste, and touch are impaired. Some persons feel sleepy. All observers are agreed that the compressed-air chamber increases the amplitude of the respirations and also the pulmonary capacity. According to Von Vivenot, it is about 3 per cent., but Paul Bert puts the figure as high as 7 per cent. The upper limit of the hepatic dulness necessarily descends, the cardiac area of dulness is decreased, and the heart sounds become muffled. The frequency of the respirations is much diminished ; they often fall to twelve or thirteen per minute. Should the patient be suffering from any pulmonary disease which renders the breathing difficult it often becomes easy, and the extremely rapid respirations of emphysema may fall to normal. The amount of urea is increased, more oxygen is taken in, and more carbon dioxide is given off. The pulse is small and slightly less rapid than before the bath. The other changes are not of sufficient importance to be mentioned here.

It is well known that bridge builders, divers, &c., who are in their occupation subjected to great increases of atmospheric pressure, frequently suffer from bleeding at the nose and lungs, and paralysis of the lower extremities and bladder. These symptoms, however, are not due to the compressed air, but to the suddenness with which the workmen come out of it into the ordinary atmosphere. Therefore, it behoves us to increase and decrease the pressure in a compressed-air bath gradually. The usual duration of the stay in the bath is two hours : of this time the first half-hour should be occupied by gradually raising the pressure to the desired point, then it should remain at that point for an hour, and the last half-hour should be occupied by the decrease of the pressure. Many diseases have been treated by it, but only the more important need be mentioned here.

Pulmonary Emphysema.—It is for this condition that the compressed-air bath has given the most satisfactory results. After several baths, one taken each day for several days, the breathing becomes easy, the dyspnœa diminishes, the cough and expectoration are decreased, the respirations become slower and deeper, the cardiac and hepatic dulness reappears, and the breath sounds over the emphysematous lung become more audible, the vital capacity increases, and the girth of the chest is lessened. The exact cause of the benefit is not known. The usual course is to take a bath lasting two hours once a day for thirty consecutive days.

Bronchitis.—This disease is often benefited by a course of compressed-air baths, but it is so difficult to separate bronchitis from its accompanying emphysema that it is impossible to say how much of the benefit is due to the treatment of the latter condition.

Phthisis.—The reason why compressed air is used in this disease is that it is supposed to open out every healthy portion of the lung and to increase the general nutrition. It is therefore chiefly indicated in those sickly pale subjects afflicted with phthisis and who have ill-formed chests. It is said to prevent the development of phthisis in those who present the above symptoms without having any actual signs in the lungs. The contraindications to its use are high fever, great weakness, severe pulmonary hæmorrhage, and decomposing processes going on in the lungs.

Asthma.—It is stated that this malady is much improved by compressed-air baths. Undoubtedly if the asthma consists only of those asthmatical attacks which are so commonly met with in the subjects of emphysema, the treatment will as it relieves the emphysema diminish the frequency of the

asthma-like attacks. It is, however, doubtful whether it has any effect on genuine neurotic asthma.

The other diseases which may be treated by compressed air may be found described in the author's 'Text-book of General Therapeutics.'

Electric Baths

All that is necessary for an electrical bath is some arrangement for sending the current, either faradic or galvanic, through the water of the bath. A form used by Dr. Russell and described by Beard and Rockwell in their 'Medical and Surgical Electricity' is thus arranged. A long bath of ordinary shape is taken. A broad copper plate as long as the water is deep is attached to the bath at either end of it. These plates are the poles of the battery. At the head of the bath a board is placed a little distance from the end; it is sloped conveniently and has a slit in it, the shape of the patient's back, so that he can lie against it comfortably. When now the current passes some of it must pass through the body. Some electric baths are so arranged as to allow the current to pass through a part only of the body.

It has not yet been proved that electrical baths are superior to the more easily applicable methods of using electricity, but it is claimed that they are particularly serviceable for rheumatoid arthritis and general exhaustion.

BATH AND BATHROOM

All the houses built nowadays for the accommodation of the middle and upper classes are provided with bathrooms. If the house is small one bathroom is sufficient, but if it is large there should be one on every floor.

The bathroom should not open out of a bedroom unless it is to be used solely by the occupants of that bedroom, for the noise of the inflow of water is very disturbing to those who are asleep, and of course it is an extremely bad plan for the only means of access to the bathroom to be through another room. The writer remembers to have seen a bathroom in the country which could only be reached by going through the drawing-rooms. It is preferable to have the bathroom at the side of the house, not in the centre, so that the waste water can be easily conveyed away to the outside. In small houses the water-closet is often placed in the bathroom: this is not to be commended, for the water-closet is useless to the rest of the household when the bathroom is occupied, and further, if owing to imperfections in the water-closet any foul air proceeds from it the bather will inhale this air during the whole of the time he is in the bathroom. Nevertheless it is often convenient to have a water-closet close to the bathroom. The walls of the bathroom that are next to the bath should either be tiled, painted, or papered with glazed paper, so that it will not hurt them to be splashed. Frequently the ceiling and wall near to the hot-water pipes is blackened by the current of hot air coming from the neighbourhood of the warm pipes and depositing dirt in their course. The best way to get over the difficulty is to paint the ceiling instead of whitewashing it, for then it can be frequently washed. What is sold as cork carpet forms a good covering for the floor, for it is warm, smooth, and easily washed; the only objection to it is that when washed it takes some hours to dry, as the cork soaks up the water. Another good plan is to cover the floor with linoleum and to have a square of cork on which to step on leaving the bath. It is very important that a bathroom should be well ventilated, for when a hot bath is being taken the air becomes

disagreeably warm and moist. It is unnecessary here to indicate the various means used for ventilating a room; they are fully described in another article. A fireplace in a bathroom is a desirable luxury, for a fire by which to dry one's self is often desirable for an invalid.

The materials commonly used for making a bath are iron, zinc, copper, porcelain, slate, and concrete. Iron, zinc, and copper are always enamelled on the interior. Iron and zinc are the cheapest at first, but they require very frequently to be re-enamelled at least every three or four years if the bath is in constant use. This is expensive, and to do it the bath has to be taken away for a few days. With an iron bath the enamel is particularly liable to flake, because the metal is very inelastic, and is easily oxidised by moisture. Zinc baths, in addition to the disadvantage of flaking, soon change their shape, so that the bottom does not remain level, and consequently all the water will not run out. Copper baths are very durable, do not alter their shape, nor are they easily oxidised; but they are expensive, and the enamel comes off as with any other metal bath.

Slate baths have the objections that as they are put together in slabs they are liable to leak at the joints, and dirt collects in the corners. If they are not enamelled it is difficult to see when they are clean, and if they are enamelled the enamel soon flakes off.

Concrete baths have only recently come into use, so that at present we cannot say whether they wear well. They are heavy and cumbersome.

Glazed fire-clay baths, or, as they are commonly called, porcelain baths, are undoubtedly the best, for they have in the interior a smooth surface with rounded corners, so that they are very easy to keep clean; the glaze keeps on an indefinite time, so that they always look nice, and they are extremely durable. The chief objection to them is the primary cost, for they are rather more than twice the price of an enamelled iron bath, but they are cheaper in the long run, for owing to the frequent enamelling in a few years the total cost of the iron bath exceeds that of the porcelain. The porcelain baths, owing to their great weight, are difficult to fix in position, but fixed no removal is ever necessary. A porcelain bath abstracts heat from the water rather more rapidly than a metal one does, but the difference in this respect is not sufficient to be of any practical importance. One of the chief reasons why porcelain baths are dear is that several are spoiled before one perfect one is made; the result is that they can often be obtained at a lower cost if one be bought with a slight blemish at the top, where it does not really matter. When once they are fixed they are not particularly liable to get broken. Owing to their durability they are very suitable for public institutions.

Both hot and cold water should be supplied to the bath, and the supply pipes should be sufficiently large to allow the bath to fill rapidly. They should not run under the bath, as then if they get out of order they are difficult of access. In some baths the water, either hot or cold, or both, flows in through the same pipe as that by which it leaves the bath: this is a particularly objectionable arrangement, for the inflowing water washes back into the bath all the dirty soap-suds that are lying in the waste-pipe. A very common arrangement is for the hot and cold water to come into the bath at the bottom by separate apertures, and for the taps which are just outside the bottom of the bath to be worked by handles at the level of the top of the bath; the handles are connected to the taps by long vertical iron rods. These taps are very liable to leak and to work badly, for the iron rod is almost certain in time to bend a little one way or the other. The best manner of introducing the hot and cold water is for the supply pipes to

come vertically up the outside of the end of the bath, for there to be screw-down taps at the level of the top of the bath, and for the water to come in at the top and fall down into the bath at the end. Most baths are slanting at one end and vertical at the other; the taps are best placed at the vertical end. The hot water is usually supplied from a high-pressure kitchen boiler. All apparatus by which the water is heated in the bathroom itself by gas should be avoided, as the fumes of the gas are very objectionable and even dangerous.

The diameter of the outlet pipe for the waste water is usually too small. It should be two inches for the bath to empty with proper rapidity. It is of course no use to have an ample waste-pipe if the perforated holes through which the water flows out or the water-way of the outlet tap are too small. The outlet pipe should always open directly into the open air, and the water should fall some distance before entering the pipe which is going to convey it directly to the drain. This is most important in order to prevent the back flow of sewer gas into the bathroom. It is not a bad plan to conduct the bath water into the gutter of some adjoining roof.

There should always be under the bath a leaden tray about two inches deep with a pipe from it into the external air. The object of this is to catch and carry away any water which may come from any leak in the taps, pipes, or bath. The overflow pipe from the bath should be at least two inches in diameter, and should go directly into the external air. It cannot be too strongly urged that no pipes proceeding from the bathroom must communicate directly with the drains. Any draught that comes up the various pipes leaving a bathroom may be prevented by providing the exit orifice with a flapper.

The bath and its pipes are usually surrounded by a wooden casing with a door so arranged that the pipes, corks, and leaden tray can be easily inspected. This is, on the whole, the best arrangement, for it is very difficult to clean away all the dirt which collects under the bath if it is exposed. Some metal baths are, however, made to stand on claw feet, and they are painted on the outside, so that a casing is not necessary.

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THE DWELLING

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THE DWELLING

Of all conditions that are prejudicial to the healthfulness of the dwelling, air that has been rendered impure is the most productive of evil. The late Dr. Edmund A. Parkes has truly said that a healthy dwelling must comprise the following five conditions :—

1. A site dry and not malarious, and an aspect which gives light and cheerfulness.

2. A ventilation which carries off all respiratory impurities.

3. A system of immediate and perfect sewage removal which shall render it impossible that the air shall be contaminated from excreta.

4. A pure supply and proper removal of water by means of which perfect cleanliness of all parts of the house can be insured.

5. A construction of house which shall insure perfect dryness of the foundations, walls, and roof.

It will be observed that in these conditions purity of air, and in that purity must be included cleanliness, is the fundamental principle aimed at. Notwithstanding the apparent simplicity of these principles, and the obviousness of the necessity for each and all of them, it is, unfortunately, rare to find, even in the present day, a dwelling in which due attention has been paid to them. In the past, neglect of these principles has led to plague and pestilence to an extent which it is difficult for us to appreciate, and, were similar neglect to exist now, when the population is so far more numerous and dense than formerly, who can conjecture to what magnitude the disastrous results of such neglect might attain? We are reminded every now and again by comparatively small local outbreaks of disease, of the necessity for paying due attention to this question of purity of air and cleanliness; but how can we estimate what would be the results were such a plague as that which visited London in 1665 permitted to get firm hold of the London of the present day, with its five millions of inhabitants and its means of almost hourly communication with all the large towns of the provinces?

It is well to bear in mind what were the ravages of that plague, and the rate at which it progressed. Thomas De-Laune in his 'Memorials of London,' 1681, after giving accounts of many other previous plagues and epidemics, says :—

In the beginning of May (1665) the Bill of Mortality mentions nine that died of the plague, and decreased the next week to three, then increased to fourteen, next to seventeen, next forty-three, and then great persons began to retire into the country. In June the bill increases to 112, next 168, next 267, next 470; then do many tradesmen go into the country, and many ministers take occasion to absent themselves from their charge. In July the bill rises to 725, then to 1,089, next 1,843, next to 2,010. Now most parishes are infected, a vast number of houses are shut up, no trade at all, and the number of dying persons still increasing, although so many thousands left the city. In August the bill rises to 2,817, next 3,880, next 4,237, and then 6,102, all which died of the plague besides other diseases. Now there is dismal solitude in London streets, every day looks with the face of a Sabbath, observed with greater solemnity than it used to be in the city. Shops are shut up, very few walk about, so that grass begins to spring in some places. A deep silence everywhere, no ratling of coaches, &c., no calling in customers, no London crys, no noise but dying groans and funeral, knells, &c. In September the bill rises to 6,988, the

next falls to 6,544, but then rises again to 7,165, which was the greatest bill. There were but four parishes that were not infected, and in them few tarried. The next bill falls to 5,538, then to 4,929, then to 4,327, then to 2,665, then to 1,421, then to 1,031. First week in November it rises to 1,414, but falls to 1,050, then to 652, then to 333, and so lessened more and more to the end of the year, when we had a bill of 97,306 which died of all diseases, which was 79,000 more than the year before, and the number of them which died of the plague was reckoned to be 68,596 that year; but others say that there died of that fatal disease, in little more than a year's space, near 100,000 persons in London and some adjacent places.

Such was the penalty paid by the community for allowing the houses to be crowded together, with narrow and crooked alleys and passages which served as streets, to which sunshine never had access, and which did not permit of proper circulation of air; for failing to provide any efficient means for the removal of the filth and sewage, which remained on the street surface until washed away by rain; and, in fact, for allowing a dense city to grow up without any efficient control in its growth or management.

The fearful ravages above recorded, however, give us only the death-roll consequent on that terrible epidemic. This outbreak of plague was only the culmination of a long series of shockingly unhealthy conditions which had previously caused repeated outbursts or 'explosions,' but which at length developed to the enormous extent set forth by De-Laune. These preceding conditions must have affected the general health of the population to a degree which it is impossible to estimate, and of which there is no sort of record, direct or indirect.

The circumstances under which outbreaks of disease occur nowadays, terrible as they appear to us, are very different; even the occurrence of many cases of typhus in some densely crowded quarter of a town is a small matter compared with the plagues of old, which ran their course until they had literally exhausted the supply of subjects to attack; and the magnitude of the old epidemics is now rarely approached, notwithstanding the vastly increased facilities that exist for the spread of disease, owing to growth and intercommunication of the population.

The lessons that have been taught by the great epidemics in the past indicate three important factors in regard to the healthy conditions of towns: 1. That there must be wide streets with frequent cross streets, and also ample open space about the houses, so as to promote the free circulation of air. 2. That the internal arrangements of the individual houses shall be such as will conduce to their efficient ventilation and to the purity of the air inside them. 3. That the administration of the town shall be such as to ensure the unstinted supply of pure and wholesome water, the effectual removal of all sewage and liquid refuse, and the regular and thorough scavenging and removal of refuse. These three conditions are requisite wherever a few dwellings are clustered together.

That they have been generally seriously neglected is evident in all parts of the kingdom, and the results are demonstrated by the unhealthy conditions that so frequently form the subject of official investigation either by the local health officers or by the inspectors of the medical department of the Local Government Board. As regards the first, the results of past neglect of control in the laying out of towns is demonstrated by the vast expenditure of money that in recent years many local authorities have found themselves compelled to incur for the acquisition, under statutory powers, of extensive areas of insanitary properties in order that the buildings may be demolished, and that new streets of greater width may be laid out, and new houses having adequate air space about them may be erected. In this way millions of pounds sterling have in the last thirty or forty years

been spent in the metropolis and in some of the principal towns of the provinces. In many districts of London where houses were huddled together in the closest possible fashion, and contained populations of great density, areas have been cleared and comparatively broad streets with improved buildings have been erected on them. In the same way in Liverpool, in Birmingham, in Newcastle-on-Tyne, in Leeds, and elsewhere, similar improvements have been made; and although in some respects, as will be described later on, these changes leave much to be desired, they nevertheless have exercised a very marked improvement on the health conditions of the localities.

The way in which some of these insanitary areas were allowed to grow up is not without its special interest, and the study of the growth of such areas ought to teach a lesson worthy of application in numbers of towns now growing rapidly in size and population, and which, indeed, may perhaps not grow to be quite so bad as some of the places already referred to, but which are most certainly allowing a very unwholesome aggregation of houses and population to occur, and cannot fail to involve serious difficulty and expense in the future. This growth of unhealthy areas may be seen in most of our larger towns and in many of the smaller ones and even in many villages, while at numbers of seaside 'health resorts' the process of crowding houses on area has been going on until within quite recent years, and in others it is still going on.

Thus one may see in streets of very modest width rows of what were once convenient houses originally built for single families, and had a good depth of garden at their rear. These, owing to the altered character of the neighbourhood or local changes in trade or manufacture, have come to be occupied by many families in each house; narrow passages or courts have been formed at intervals through the ground storey in order to give access to blocks of smaller houses that have been built on the garden ground at the rear, and in between these have been wedged the scanty privy and ash-pit accommodation for the dense population now occupying the area. In the older parts of many watering places, which during the summer months are crowded with visitors, so that the population is trebled or quadrupled, it will be found that the yard originally left at the rear of many of the houses is almost wholly obstructed by a small house which has been built in it, to which the proprietor retires during the letting season in order that the main house may be freed for the occupation of the visitors; and thus the smaller backhouse has no means of through-ventilation whatever, and only a small and confined well of stagnant air in front of it, which also has to serve as the open space at the rear of the front main house.

The reports of the Medical Officer of the Privy Council and Local Government Board refer to many instances tending to show that crowding of houses on area and corresponding density of population are attended with endemic and epidemic disease. Thus in the report[1] by Dr. George Buchanan on epidemic typhus at Greenock, in 1865, it is shown that Greenock had an excessively high general death-rate, due to a large extent to the deaths of children, as well as to special fatality of lung diseases and consumption, and likewise to the then recent epidemic prevalence of measles, scarlatina, smallpox and diphtheria, each of which diseases had affected the town with exceptional intensity. The cause of the great epidemic prevalence of fever was attributed entirely to overcrowding and the dirty habits of the people, little or no influence being ascribed to defects of drainage, and any exceptional destitution being at that time wholly wanting

[1] See *Eighth Annual Report of the Medical Officer of the Privy Council*, Appendix, p. 209.

as a causative element. The crowding of tenement houses on area is described in that report as prevailing to a remarkable extent in the old part of Greenock, every particle of ground that was not street being covered with buildings. It is said that some air trickles between the tops of the tenements and may get into the upper tenements, but in not a few of the lower ones the back rooms receive no breath of air or ray of light. The description given of the crowding of persons within the houses is even more striking.

It is remarkable how this crowding of population on area has grown up in the course of centuries; comparatively speaking, very few new towns have sprung up, and nearly every town and village throughout the land owes its origin to, and indeed has some sort of evidence in proof of its existence in the time of the Romans, the Saxons, or the Normans; thus, even in those days, the country was studded with villages lying between the greater towns, and many of these have since grown to be chief provincial towns or cities, the growth of which has been partly circumferential, but in a large degree caused by the closer packing together in the centres. This is shown in a very clear manner in one of the annual reports of the Medical Officer of the Local Government Board.[1] In anticipation of the country being visited by cholera, the Board caused a sanitary survey to be made of the coast towns where cholera might be imported from infected countries and of a large number of other towns where it was known that other diseases spreading under somewhat similar circumstances to cholera—e.g. enteric fever or epidemic diarrhœa—habitually prevail. In this survey special attention was directed to the general condition of the dwellings of the poor and labouring classes, and specially to the prevalence of crowding of dwellings on area as well as of overcrowding within dwellings. The tabulated *précis* of the reports upon the various places surveyed showed some striking instances of crowding of houses on area about narrow courts and streets; and this notably in the cathedral and university towns.

The provision of ample open space in our towns in the form of wide streets, cross streets at frequent intervals, public squares, boulevards, and parks and gardens within easy reach of the inhabitants, especially the children, where they can assemble in the open air for exercise and recreative purposes, has in the past failed to receive as much attention in the laying out of districts as it deserves. In some of the large proprietary estates of London—e.g. the Grosvenor, the Penton, the Bedford, the Portland, and the Portman Estates—some splendid squares and streets have been formed, which have been of enormous benefit to the inhabitants, and in a scarcely less degree to the public; but wherever the land has been in the hands of small owners it has been subject to all the disadvantages of the numerous individual interests; and, in the total absence of any legislative requirements, improvement of this kind has been impracticable.

Such open areas as have just been referred to are as indispensable in their way in our towns and cities as are the open spaces now commonly required about individual houses, and yet no laws have hitherto been framed for making the provision of them compulsory. Some slight efforts have been made in recent years to increase the voluntary provision of open space in thickly populated areas; thus, for the metropolis, the Metropolitan Open Spaces Acts of 1877 and 1881 have given facilities for the acquisition, maintenance, and regulation of open spaces and burial grounds by the local authorities of the metropolis for the use of the public for exercise and recreation, and authorise, for the

[1] *Fifteenth Annual Report of the Local Government Board*, 1885–86. Supplement containing [c. 4873] 'Reports and Papers on Cholera submitted by the Medical Officer of the Board.'

purposes of those Acts, the expenditure of such funds as those authorities have at their disposal. Similar facilities for making open spaces and burial grounds situated in the provinces available for the like use by the public are also afforded by the Open Spaces Act, 1887,[1] which latter Act has amended the previous Acts in several particulars, and has rendered most of the amended provisions of those Acts applicable, with the necessary modifications, to every urban and rural sanitary district in England and Wales. Under these Acts powers are given to local authorities to acquire, either by purchase or gift, and to trustees and other persons and corporations under disability or possessing limited interest, to transfer open spaces and disused burial grounds to the sanitary authorities in order that they may be held in trust and maintained, and if necessary be laid out and improved with a view to their enjoyment by the public in an open condition, free from buildings and under proper control and regulation.

These Acts should be constantly borne in mind by local sanitary authorities and their officers, especially in districts where the population is rapidly increasing and the ground is being speedily covered with buildings, in order that a due amount of open space, over and above what is afforded by streets of ordinary width, may be secured to the public at a time when it can be acquired without much difficulty and before the erection of houses over the whole district renders the acquisition of such open space practically impossible. The provision of open space for the use of the public ought of course to be made with due regard to its equable distribution over the population, since the greatest benefit would result from its proximity to the several parts of the districts. Hence, a broad boulevard all round a town or directly through it would be one of the most useful forms of open space; or, again, a number of open squares situated in different parts of a town would be of more general use than a single park of even large extent situated at one end of the same town. If, when a town aspires to be incorporated as a borough, it were required, as a condition of its promotion, to acquire and set apart for the use of the public a certain extent of land as open space for exercise and recreative purposes, what vast benefits would result to the inhabitants! It may be difficult to lay down any proportion of area to population as a minimum, but a comparison with what exists in certain towns and cities would serve as some sort of guide to assist in considering what might be fairly demanded.[2] Much is undoubtedly being done in the

[1] 50 & 51 Vict. cap. 32.

[2] The number of persons per acre of open space is given by E. R. L. Gould in the publications of the American Statistical Association as follows:—

	A	B		A	B
In London	694	909	In Boston	301	529
Paris	495	985	Baltimore	376	1,749
Berlin	804	1,314	Philadelphia	340	17,649
Edinburgh	246	672	Cincinnati	678	1,528
Vienna	473	3,305	St. Louis	164	460
Manchester	2,230	—	Washington	361	451
New York	994	3,334			

The figures in column A hardly give an accurate notion of the proportion of open space which the inhabitants of the several cities and towns really enjoy, partly because of the great differences in the width of streets, and partly because of the differences in the way in which the open space is distributed. Accordingly, column B is introduced in which thearea of the largest distinct park in each city or town has been omitted, and the result shows in some instances a vastly increased number of persons to the acre. But as regards absolute proportion of open space to population, Washington appears to be far ahead of any large city in the world, and it has also the greatest relative number of small open spaces—*The Sanitary Engineer*, New York, Jan. 5, 1889.

way of providing open spaces. The acquisition of various areas in the suburbs of London is a most valuable provision for the public good, the magnificent roads that are being formed in some districts—e.g. that in the Toxteth Park district at Liverpool leading out to Princes Park—all show that the necessity for open spaces is recognised, but much still remains to be done, and the public have to be led to understand the necessity for it.

The question of density of population is one that cannot properly be overlooked in connection with the hygiene of the dwelling. It has been affirmed that the density of population affords no index of the death-rate, but, notwithstanding, it is shown in the annual reports of the Registrar-General that the highest death-rates occur in the most densely populated areas, and that infant mortality in general, and diarrhœa in particular, prevail wherever there is great aggregation of population. Doubtless this is to some extent to be accounted for, partly by the social habits of the people themselves and partly by defective local administration, such as improper scavenging and insufficient water supply, but perfection of these matters will not alone suffice to place the sanitary state of a densely populated area in the same condition as an equally well-cared-for area, where the population is sparsely distributed. Where there is considerable density of population, it follows that the houses must be packed very closely together, that the rooms must be occupied by numbers of persons approaching what is known as 'overcrowding,' and that the houses may even be of excessive height in proportion to the open space about them. According to the minimum open space about houses required by the Model Bye-laws of the Local Government Board, the largest number of water-closeted cottage dwellings that can be got on an acre of land is forty-eight when each house has a frontage of 14 ft. 9 in. and contains a living room and scullery in the ground storey, two bedrooms in the upper storey, and an attic room, and if privies are substituted for water-closets, and the requisite back streets are provided for the removal of ashes and privy refuse, the number of similar houses would be only forty-one or forty-five, according to the width of the back street.[1] Supposing that each of these houses is occupied by an average of five persons, the density of population would be represented by a rate of 240 persons to the acre in the former instance, and from 205 to 225 to the acre in the latter instance.

In some of the blocks of artisans' dwellings that have been erected in the metropolis this rate is very largely exceeded. Thus, from the evidence given in 1884 before the Royal Commission on the Housing of the Working Classes the density of population is stated to be, in some instances, at the rate of about 1,000 persons to the acre,[2] and the health of the inhabitants, judged by the mortality statistics, is stated to be satisfactory. In these instances the buildings were designed to be six storeys in height, and, notwithstanding certain objections raised by the Home Office to their great height, those objections were ultimately waived, and a height of six storeys eventually became the rule,[3] and even this has since been exceeded. In some instances, however, these buildings were so crowded on the area that, owing to their height, to the limited amount of open space in the internal court or 'playground' and about the exterior, to the absence of openings at the angles of the court, and of sufficient openings from the court into the adjacent streets, there were serious impediments to the access of sunshine and to free circulation of air about them, with the result that the health conditions of those particular buildings, though the fittings and details of construction were

[1] *Report on Back-to-back Houses.* By Dr. Barry and Mr. P. Gordon Smith. London: Eyre & Spottiswoode, 1888.

[2] Q. 11812 and 11813.

[3] Q. 11848.

identical with those of other more healthy buildings, were reported to be far worse than others, the rate of infant mortality specially being much higher in them than elsewhere.

In the recent report to the Local Government Board by Dr. Ballard upon the causation of the annual mortality from diarrhœa [1] he points out, among the more important conditions influencing diarrhœal mortality, that aggregation of population favours, and dispersion over area disfavours, diarrhœa; that density of buildings (whether dwelling-houses or other) upon area promotes diarrhœal mortality; and that restriction of and impediments to the free circulation of air, both about and within dwellings, promote diarrhœal mortality. There are, it must be admitted, many strong reasons for allowing, in some cases, considerable aggregation of population on area, and within certain limits and under certain conditions as regards local administration, it may be permissible, in such cases, to approach, though scarcely to reach, the very high rate of density above referred to. But it appears certain that high rates of density cannot be allowed with impunity, and that some limit must be determined upon. Overcrowding, in the form of an abatable nuisance, has a statutory limitation to an individual house or part of a house, and the only way by which such vast numbers can be aggregated on area is by piling up houses one upon another in the form of tenements, and so long as the height to which buildings may be carried remains unlimited by law, this method of providing house accommodation will go on extending. A single building of abnormal height here and there may, in itself, be of little harm; but when repeated in near proximity one to another the conditions would become serious. At least, some means ought to be found for securing adequate open space about every such high building. This would not only suffice for securing freer circulation of air about the dwellings, but it would at the same time have the effect, indirectly, of placing some moderate restrictions on the number of persons to be provided for on any given area. In the recommendation of the Housing of the Working Classes Committee of the London County Council, which was adopted by the Council at the end of 1889, it is suggested that the distance between any block of dwellings and the nearest building obstructing the light from its windows should, if practicable, be equal to one and a half times the height of the obstructing building. But it is anticipated that, in view of the cost of land in the metropolis, such distance cannot be generally provided. It is, however, laid down that 'under no circumstances should a nearer distance than the height of the buildings be allowed.' It remains to be seen how far even this modification of what is considered most desirable can be complied with. That it is an excellent rule in the interest of health can scarcely be questioned, but the difficulties of strictly adhering to it where questions of finance occur appear to be almost if not quite insuperable.

In reviewing the dwelling accommodation of the population of such a country as the United Kingdom, it will be found that it may be classified somewhat as follows:—1. There are the mansions and large houses of the nobility and wealthy, studded all over the country and in the best parts of the metropolis. 2. Then there are the smaller houses and villa residences of the so-called middle classes, occupying perhaps equally good positions but much smaller areas of site. 3. Next to these, and scarcely differing in accommodation, are the terrace houses of the same class, clustered more closely together, as most of the occupiers of them have to be within a certain limited distance from some neighbouring locality or place of business. 4. Closely

[1] London: Eyre & Spottiswoode, 1889. [c.—5638.]

allied to these is the class of dwelling combined with place of business. 5. The next kind of dwelling is the small house or cottage of the artisan and wage-earning community—perhaps the most numerous of all—which varies, as in the other kinds of dwelling, according to locality and circumstances. 6. Lastly there is the institution in which is housed a greater or less number of persons who are gathered within its walls for some common purpose or object.

Each of these several kinds of dwellings is necessarily subject to numerous modifications, many of which must be considered distinctly under their various heads. Thus in the case of the *first class*—mansions—must be included the palaces of Royalty and of the nobility, the magnificent mansions and extensive dwellings, with their dependencies, both in town and country, of the merchant princes and wealthy manufacturers. The *second class* embraces not only the suburban and country house of the ordinary professional man of business and wealthy tradesman, whether retired or still in business, but the country parsonage and the residence of the well-to-do farmer together with the outbuildings connected therewith. The *third class* is more essentially urban, and is chiefly concerned with that vast section of the so-called middle class of the community, whether professional, clerical, or commercial, who are compelled to live in, or in the immediate neighbourhood of, towns, where land is too valuable to admit of the houses having more than is requisite for them to stand on, with a small amount of open space in front and at their rear. It must likewise include what have come to be known as 'flats.' The *fourth class* embraces the dwelling in connection with the place of business such as the ordinary shop premises with dwelling apartments above, also the hotel, inn, and such like. The *fifth class* is by far the most numerous, and the modifications of it are very varied. Thus, it must include the agricultural labourer's cottage in the country and the artisan's cottage in the manufacturing town, the tenement house in the block of artisans' dwellings, the common lodging-house, and the accommodation let out to lodgers generally, including what are known as 'cellar dwellings.' The *sixth class*—institutions—must include residential schools, barracks, asylums, workhouses, prisons, hospitals, &c.

The extraordinary increase of population that has taken place in recent times throughout the country, and most of all in the urban parts, has necessitated the erection of vast numbers of new houses. There is apparently much difference in the numbers erected year by year in the various localities, caused no doubt by the variations in trade and prosperity as well as by a variety of local circumstances, but the numbers generally are very considerable. According to the census returns for England and Wales, there was a large increase in the number of inhabited houses during the ten years ending April 1891, the total number of such houses in April 1881 having been 4,831,519, and in April 1891, 5,460,976, or an increase of 13 per cent. There were also at the date of the census 1891, 380,117 unoccupied houses and 38,407 in course of erection; but these numbers were somewhat lower than at the date of the previous census. In the Metropolitan Police District, inclusive of the city, with its population (1891) of 5,633,332, there are 797,679 inhabited houses, and these have increased during each of the decennial periods ending 1871, 1881, and 1891 by 93,504, 117,661, and 151,984 respectively. These large figures will be more readily appreciated when it is realised that they mean that during the first of those three periods an average of thirty-one new houses were finished in the Metropolitan Police District on every working day; during the second period thirty-eight new houses were so completed; and during the third period as many as forty-nine new houses were completed, on the average, on every working day of the ten years.

It will be seen that, according to the census 1891, the average number of persons in every inhabited house was 7·6, but by far the larger proportion of these new houses are houses intended for artisans and the wage-earning classes, which let at weekly rents ranging between five and eight or ten shillings a week, or at yearly rentals of about 20*l.* to 30*l.* or 35*l.*, and in which the average number of inhabitants is probably between four and five per house.

Whatever the class, there are certain indispensable conditions of construction that are common to every dwelling, be it a palace, a labourer's cottage, or an institution in town or country alike, if it is to be such as may be regarded as healthy. Thus it must be so constructed as to be able to be kept free from damp, to be proof against weather and excesses of temperature or sudden external changes, and to maintain the air within it in a proper and wholesome condition. These indispensable conditions have for the most part been dealt with in more or less detail in the Model Bye-laws as to new buildings [1] which were issued by the Local Government Board in 1877 for the guidance of sanitary authorities when framing building regulations for their districts, and comprise the following provisions:—(*a*) the site of the dwelling must be free from offensive soil, and the surface of the ground enclosed within the walls of the building must be covered with a layer of good cement concrete in order to exclude any sort of ground air from the building; (*b*) the external walls must be of suitable material and of adequate thickness and construction such as will effectually keep out the weather and afford reasonable means of preserving to the interior of the dwelling a suitable temperature; (*c*) the whole of the walls of the dwelling, whether external walls, party walls, internal cross walls, or sleeper walls supporting the flooring of the lowest storey, must have an adequate and efficient damp-proof course to prevent moisture rising in them by capillary attraction; (*d*) the roof must be thoroughly weather-tight, and ought to be of such construction as will effectually serve to protect the interior of the dwelling not only from rain, hail, and snow, but from external heat and cold; (*e*) the means of light and ventilation throughout the dwelling must be adequate and effectual; (*f*) the means of removing waste water, sewage, and refuse of every description must be cleanly, regular, and speedy, and such as will not in any way be prejudicial to the health conditions of the dwelling; (*g*) the means of supplying, storing, and distributing water must be such as will secure an unstinted supply, and will not allow its quality to be impaired.

It may be useful here to refer briefly to the details of these several indispensable conditions in order that the necessity for them as well as their full advantage may be duly appreciated and understood.

The first of them (*a*) relates to the protection of the interior of the dwelling from exhalations from the ground upon which it is built.

If a site has been artificially made, the greatest care is necessary to ascertain that the subsoil is free from any organic matter in a state of decomposition. Sites are dealt with by the enterprising speculating builder in a remarkable manner. In some districts much profit is made out of the site before any building is put upon it: thus, the turf is first sold, then the surface ground is disposed of for garden purposes; the subsoil is then excavated, sometimes for sand or gravel, which always has a good market value, sometimes for stone, and sometimes for clay with which bricks are manufactured or which is burnt for ballast. The site is then used as a tip for rubbish of all kinds, a small fee being charged for each load that is deposited upon it;

[1] *The Model Bye-laws of the Local Government Board.* London: Knight & Co.

and when its level is raised to a suitable height, it is regarded as ready for use as a building estate. It will, therefore, be obvious that in the majority of such instances the materials deposited on the site are such as would be likely to become a source of danger to the healthiness of any dwelling that might be erected thereon. Hence in all well-regulated districts it is required under the local building bye-laws that all materials impregnated with either fæcal matter or with animal or vegetable matter should be removed by excavation or otherwise from any such site before any new dwelling is erected upon it. This may involve much cost and labour in excavation, but if a sufficient length of time has elapsed since the objectionable material was deposited on the site, the objection may possibly have been removed by the ordinary process of decay. On this particular question some very interesting experiments, having for their object to ascertain what the effect of time had been on the organic matters which, together with cinder refuse, had been used to fill up inequalities in the ground, were made by Professor Burdon Sanderson, M.D., F.R.S., and the late Professor Parkes, M.D., F.R.S., during an investigation some few years ago into the sanitary condition of Liverpool, and in their report it is stated that 'the process of decay of all the most easily 'destructible matters,' including vegetable refuse, 'is completed in three years,' while in the case of wood and woollen cloth the process was more prolonged. It is further stated that 'the vegetable and animal matter contained in the cinder refuse decays and disappears in about three years, and is virtually innocuous before that time.' In view of these statements it may, therefore, be assumed that for practical purposes three years will amply suffice for the removal by oxidation of the objectionable matters in such refuse. If, however, fæcal matter has at any time formed part of the refuse, more stringent precautions ought obviously to be taken; indeed, under such circumstances, unless all soil so contaminated were completely removed, a much longer period should be permitted to elapse before building operations could safely be allowed to commence.

As regards the necessity for covering the site of a dwelling with concrete, the sanitary advantages of this precaution are far more considerable than is commonly supposed, while the extra cost involved by it may be less appreciable than at first sight appears to be the case. Dr. Geo. Buchanan, F.R.S., in his report on the distribution of phthisis as affected by dampness of soil,[1] has shown that wetness of soil is a cause of phthisis to the population living upon it, and it has long been known that residence on a damp subsoil as the foundation for a house favours the prevalence of pulmonary disease; hence the precaution under consideration is most desirable, if only on the score of dampness. But there are other reasons which render it most essential. Ground air itself, even if not laden with watery vapour, may contain material that it is most important to keep out of the dwelling, such as carbon dioxide or it may be poisoned by the soakage from a neighbouring leaky drain or sewer, or from an ashpit or a cesspool. Even if the street in front is not flagged and paved, and the yard behind is not flagged or asphalted as it ought to be, the ground surface outside the house is quite impervious during a hard frost, and the chimneys and fires in the dwelling exercise to a certain extent a process of suction on the ground immediately beneath the dwelling, and a quantity of ground air with all its impurities may easily be drawn into it. Nor is this by any means a mere theory, since instances are on record of ordinary coal gas having been thus drawn a considerable distance beneath the frozen surface of the ground, from a leak in the gas main under a road to the interior of a neighbouring dwelling-house. It

[1] *Tenth Report of the Medical Officer of the Privy Council*, 1867.

is, therefore, most desirable that the surface of the ground under every dwelling should be covered with a layer of good cement concrete, 4 to 6 inches thick, and floated over to a smooth top surface with fine sand and cement so as to form a close and impermeable floor. This concrete may serve in many instances as the floor itself, and thus save the cost of any other flooring. Such concrete floor would generally suffice in passages, halls, staircases, sculleries, washhouses, pantries, and perhaps in kitchens and other offices. Moreover, where a boarded floor is used, a space of at least 9 inches has to be left for ventilation and as a precaution against dry rot in the floor timbers, between the underside of the floor-joists and the ground-surface, whereas if the latter be covered with such a layer of concrete as is above described, the distance between its surface and the underside of the floor-joists may, without impropriety, be reduced to, say, 3 inches, thus effecting a saving of two courses of bricks (6 inches) in the height of all the walls of the building—an item which would go some way towards meeting the cost of the concrete.

The second (*b*) of the indispensable conditions above referred to concerns the external walls of the dwelling, and the character and construction of these will depend to a certain extent upon the aspect and situation of the building. Ordinarily a brick wall only 9 inches thick is not sufficient to keep out the weather, especially if in anything like an exposed position. The bricks are of a porous nature, and driving rain will be forced through them, and show itself in the shape of moisture and dampness on the inside. A common stock brick will absorb as much as one pound of water, and therefore it will be readily understood that rain may easily be driven through a wall where the bricks known as 'headers' extend through the entire thickness of the wall. Indeed, air is constantly pressed through such bricks, and though this may be said to assist ventilation, it at the same time tends to lower the temperature of the interior of the house. The facility with which air may be pressed through certain kinds of bricks is shown by the common experiment of coating the four sides of a porous brick with wax and fixing a glass funnel on to each end of the brick, when sufficient air may be blown from the mouth applied to the tube of one of the funnels so as to obviously influence the flame of a candle held near the tube of the other funnel. It is desirable in all dwellings that the external walls should, if of brickwork, be at least a brick and a half—i.e. 14 inches—thick, so that there may be a vertical layer of mortar, in addition to the bricks, in the structure of the wall itself. In the case of stone walls and walls in which there is an exceptional quantity of mortar, as in rubble work, flint work, and such like, it is desirable to increase the thickness. In exposed situations it is common to construct the external walls of buildings with a cavity 2 to 3 inches wide between the external and internal faces of the wall, and to join the two portions of such wall together by means of bonding ties of some non-absorbent material placed at suitable distances apart. Sometimes these bonding ties are made of iron, sometimes of glazed stoneware, and such walls, if properly constructed, are generally sound and sufficiently stable for all practical purposes, while they greatly promote the comfort and dryness of the house itself. Other means of securing the same condition of dryness have been contrived with more or less success, such as a vertical damp-proof course of slates, or of asphalte or other bituminous substance. Compo or tiles or slates are sometimes used on the outer face of the wall for the same purpose.

The third (*c*) condition above mentioned is intended to prevent the passage of moisture vertically in the walls of the dwelling; hence the

damp-proof course must be laid throughout the entire thickness of every wall and at a level some 2 or 3 inches at the least above that of any ground adjoining the wall. It must also be below the level of any timber or woodwork in or upon the wall, as such timber or woodwork obviously needs the most complete protection from damp. The provision of an efficient damp-proof course in the external walls of a building may necessitate the formation of a sunk area against the wall in order that the earth may be kept at a proper distance from that part of the wall which, being below the general level of the ground outside, is above the level of the damp-proof course. This is essential if the dryness of the wall is to be preserved. Modifications of this kind of construction have sometimes been adopted by which the outside of that part of the wall which is above the level of the damp-proof course and below that of the adjacent ground has been covered with asphalte or other impervious material, or that part of the wall has been constructed with a cavity and a second damp-proof course at the level of the top of the cavity; but these are contrivances more adapted to meet the requirements of certain exceptional circumstances, and need not here be referred to in further detail. A damp-proof course is often requisite in the case of chimney stacks and parapets in order to prevent damp from driving rain soaking downwards from the exposed upper portions of walls of buildings.

The fourth point (*d*) above referred to is the construction of the roof of the dwelling of such material and in such manner that it will serve its purpose of efficiently protecting the interior of the dwelling from the weather—wet, heat, and cold. Roofs are covered most frequently with slates or tiles, but sheet lead and zinc are occasionally used for the purpose, and almost invariably for gutters and valleys, cast iron being most commonly used for eaves guttering. Thatch, though affording perhaps the greatest opportunity for picturesqueness, is now rarely used for new dwellings, as it is less durable than the other materials, and is regarded as a possible source of danger from fire. It is, moreover, not free from objection on sanitary grounds, since it is entirely vegetable in its nature, and therefore undergoes comparatively rapid decomposition, which is encouraged by the changes of weather to which it is exposed. It likewise affords harbour for insects and vermin, and has been suspected of retaining the infection of scarlet fever after that illness had been under treatment in a cottage with such a roof.[1] Slates, if properly laid and with a good 'lap,'[2] which ought not to be less than three inches, may perhaps be regarded as affording the best ordinary roof-covering in our climate, but they ought invariably to be laid on boarding and felt, and not merely on laths as is too frequently the case; otherwise they allow the interior of the house to be unduly affected by external temperature. In this respect tiles have the advantage, as they afford a better protection from heat and cold. A tile roof has to be constructed with a steeper pitch than a slate roof, as the latter material affords greater facility for rain water and snow to run off than a tile-covered roof. It is, of course, necessary to provide suitable guttering along the eaves and elsewhere, to collect the water from the roof before conveying it away down the rain-water pipes. And, as regards these latter, it is desirable to fix them at a short distance from the walls of the building in order to protect the walls from damp in the event of a down pipe getting stopped up. Cast-iron rain-water pipes are often made with a special fastening that keeps the pipe itself an inch or two away from the face of the wall.

[1] *Our Homes*, p. 8. London: Cassell & Co., 1883.

[2] The 'lap' in slating is the distance that each row of slates overlaps the head, or upper edge, of the second row of slates below it.

The fifth point (*e*) referred to concerns the light and ventilation of the dwelling, and although the latter forms the subject of a special article elsewhere, it may nevertheless be useful to draw attention to certain features that are indispensable to the dwelling under this head. First there is the necessity for providing adequate open space, not only at the rear of every dwelling, but also in front thereof, and the importance attaching to this provision is shown by the stringency with which regulations for securing the requisite minimum amount of space are laid down in the Model Bye-laws, already referred to. It is there prescribed (clauses 53 and 54) that a clear distance of open space, at least twenty-four feet across, measured to the opposite side of the street, if necessary, is to be provided in front of every new dwelling-house, and also that an open space belonging exclusively to it, extending laterally throughout the entire width of the building, is to be provided at the rear, measuring from a minimum of ten feet up to twenty-five feet across such space, according to the height of the building, of every new dwelling. It is further prescribed (clause No. 55) that adequate windows are to be provided in each storey of the building in the walls which abut upon the open space so required to be provided; and likewise (clause No. 57) that every room intended for the purpose of habitation shall have at least one window, the size of which is to bear a proportion of one-tenth of the floor area of the room, that such window is to be made to open to at least half its size, and so that the opening may extend to the top of the window. These regulations thus have the beneficial effect of practically prohibiting the use of skylights in substitution of proper vertical windows, for the purposes of lighting and ventilating every room in a dwelling. So also with regard to the ventilation of a water-closet or earth-closet in a dwelling house; not only ought it to be furnished with at least one window of a minimum superficial area of about two square feet, opening directly into the external air, but it should have, in addition, a second opening of some sort, such as 2-inch Tobin tube or some kind of ventilating air brick, in order to promote the circulation of air through the closet independently of the air of the house itself. These requirements, which, where carried out, greatly tend to keep the air of the closet pure by the rapid removal of offensive odour, are specially prescribed in the Model Bye-laws (clause No. 68).

The details of the sixth point (*f*), relating to the removal of the liquid and solid refuse from the dwelling, are likewise dealt with elsewhere, but it is necessary here to refer to the arrangements that are requisite for receiving the filth and refuse before they pass into the channels of removal. These arrangements usually comprise the ordinary water-closet apparatus, dry earth closets, and privies of various descriptions, and slop sinks, likewise ashpits and dustbins. These appliances, in one defective form or another, have been the cause of more injury to health than perhaps all other causes together. Water-closets, by bringing drains leading to sewers and cesspools directly into the dwelling, have poisoned the air within; and badly contrived privies and ashpits outside the dwelling have poisoned the air and soil about the exterior of the dwelling, as well as the water used by the inhabitants. And thus they have combined to inflict upon the people those terrible 'filth diseases,' as Sir John Simon has so aptly described them in his official reports,[1] as Medical Officer of the Privy Council and Local Government Board, which have not only carried off such vast numbers of persons, but have from time to time attacked and prostrated a still greater number. Under these

[1] See especially the report on 'Filth-diseases and their Prevention' in the *Supplementary Report* for the year 1873. New Series No. II. [c.—1066.] London: Eyre & Spottiswoode, 1874.

circumstances the question of the precise kind of closet apparatus to be adopted, whether on the *water* principle or on some of the *dry* principles, is a matter of much importance. The leading principles to be observed in either case are dealt with in some detail in the several clauses of the Model Bye-laws, already referred to (clauses Nos. 67 to 79). These clauses may be said generally to cover the whole subject, since they prescribe the arrangements to be followed in the construction of water-closets and of earth-closets and privies, with either fixed or with movable receptacles. After setting forth that every new water-closet or earth-closet is to be so placed and constructed as to ensure its efficient ventilation, the bye-laws require every new water-closet to have its separate cistern or flushing-box furnished with means for effectually flushing and cleansing the basin of the closet, and for removing the excreta therefrom. This requirement practically prohibits the use of closets in which the objectional plan of hand flushing—i.e. the occasional emptying of a pail of water into the basin, is relied upon. The necessity, for sanitary reasons, for providing the separate cistern is explained later on;[1] but, as regards its capacity and position, it may here be pointed out that in order to make the flush effectual, both as regards volume and force, it is requisite to fix the flushing-cistern at least four or five feet above the closet-basin, and to provide a pipe from the cistern to the basin of at least 1¼ inches diameter. The quantity of water requisite to flush out the basin and carry away the excreta will depend to some extent upon the particular form of basin and the kind of trap beneath it, but it will rarely be found that less than two gallons will answer the purpose, and even this will often fail to remove it further than from the basin to the trap, where the solids will remain until the next time a flush is applied. For more effectually flushing the trap and soil-pipe, as well as the basin, it would be better to use three gallons of water at a time. This quantity, though objected to by many water companies, has been advocated as necessary by many sanitary engineers and others who have paid special attention to the point, and the only alternative that can be recommended is to apply a second flush each time the closet is used. To this, however, a difficulty has been interposed in the interests of the water companies, by which, owing to the small size of the pipe supplying the flushing cistern with water, the time occupied is so great that few persons are willing to wait while the flushing cistern is getting re-charged, after the first flush has been applied to the basin. In some instances as much as eight or ten minutes elapse before it is full, and consequently, as the application of the second flush recommended is rarely practicable, it is better to insist upon the larger capacity of the cistern. But if the supply-pipe were so enlarged as to fill the cistern in, say, two minutes, the smaller capacity might possibly be regarded as adequate, a second flush being recommended on every occasion the closet is used.

The Model Bye-laws next require the water-closet to have a basin of non-absorbent material, and of such shape and capacity, &c., as will contain a sufficient quantity of water, and will allow the excreta to fall free of the sides, and directly into the water in the basin. This requirement, which is necessary in the interests of cleanliness, practically prohibits the use of the long hopper-shaped closet-basin (fig. 108) so commonly met with in cottage closets and in servants' closets, and in which the excreta invariably hang about the sides and fail to be removed by the sluggish flow of water in a spiral course round the basin. The ordinary valve-closet basin shown in fig. 109 obviously conforms with this requirement, and is one of the best

[1] See p. 667.

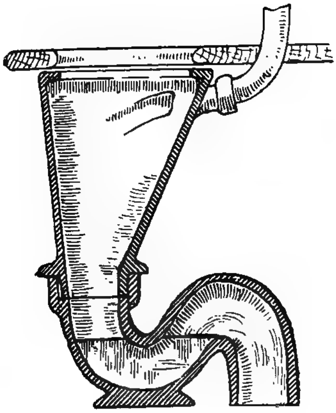


Fig. 108.

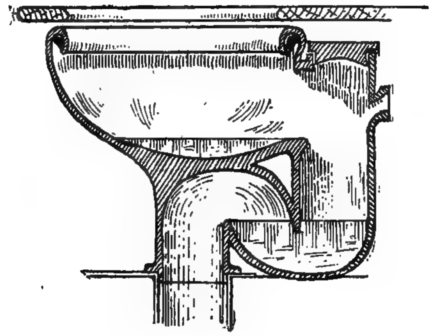


Fig. 111.

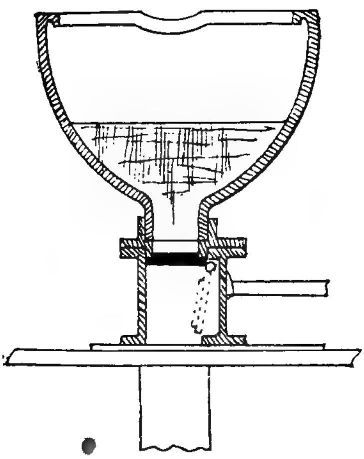


Fig. 109.

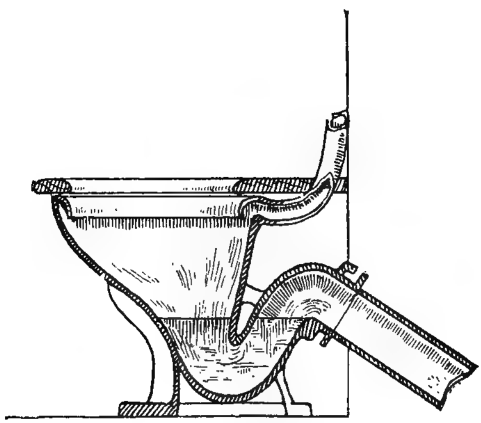


Fig. 112.

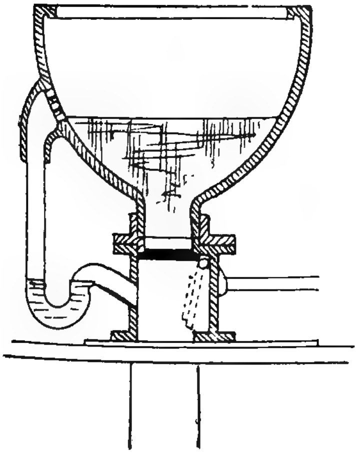


Fig. 110.

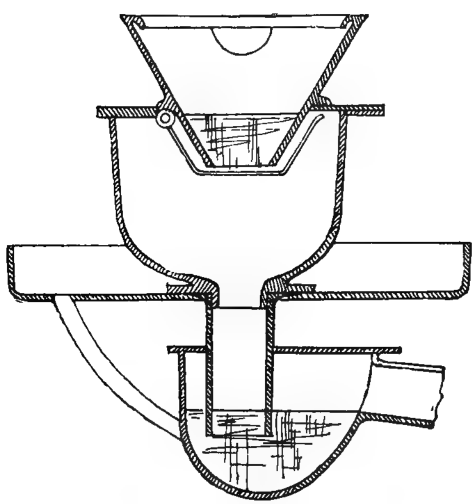


Fig. 113.

forms of closet apparatus, especially when made with a spout or lip on the edge of the basin to serve as an overflow into the safe below, instead of the overflow-pipe delivering beneath the valve as shown in fig. 110. Other forms of closet-basin complying with this requirement are shown in the 'wash-out' and hopper-shaped basins in figs. 111 and 112. The same Model Bye-law (clause 69) next proceeds to prohibit the fixing in any new water-closet of what is known as a 'container' and 'D trap.' These appliances were, for many years, most common. They are still often used notwithstanding their general condemnation by sanitarians, and are met with all over the kingdom, as well as in Continental towns. A section of this kind of apparatus, with the 'container' and 'D trap,' is given in fig. 113 and fig. 114, showing as nearly as possible the actual state of the interior of the trap after a few months' use. The two appliances referred to involve the retention of excreta in them, often for many hours together, with the result that the sides get coated over with a filthy slime or deposit which emits that offensive and most unwholesome odour invariably met with in these closets when the handle is pulled up for the basin to be emptied. The interior of these appliances not being subjected to the full force of the flush of water in the basin, the filth gets deposited over it in the way shown, and this process of deposit is much aided in the container by the use of iron, of which the container is usually made.

As regards the seventh point (*g*), the means of storing and distributing water, it is of the utmost importance that the arrangements generally should admit of an unstinted supply being available to the inmates of every dwelling. The amount per head per diem that is requisite in an ordinary dwelling depends necessarily upon a great variety of circumstances, and is dealt with in another part (see p. 243).

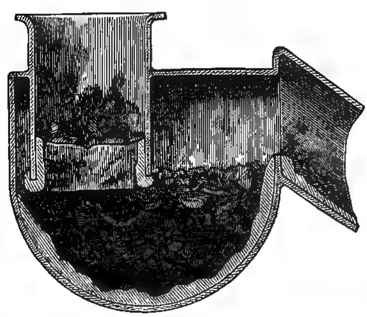


Fig. 114.

Where the supply is on the constant system cisterns are still requisite, as the supply, being through a small tap, is not always as rapid as may be temporarily necessary, and, moreover, when it is cut off for a few hours during the repair of a main, much inconvenience might arise if there were no storage-cistern of moderate capacity; but the size might be very much smaller than where the water is supplied on the intermittent system. On the other hand, there is some disadvantage in the cistern being of excessive size, as the water in it may in that case not be changed sufficiently often, and thus become affected by stagnation.

For the storage of the requisite quantity of water, tanks or cisterns are usually provided at such height above the ground as will allow of the water being delivered by gravitation where it is wanted below the level of the cisterns. These cisterns are ordinarily made either of slate, iron, lead, or wood lined with lead or zinc, and are fitted with a ball-cock or valve to regulate the admission of water from the main supply according to the level of the surface of the water in the cistern, and an overflow- or warning-pipe to indicate when the cistern is full, or when the ball-valve may be out of order, to obviate the inconvenience of the cistern overflowing. There are serious objections to the use of lead for cisterns, as certain water, especially rain-water or soft-water, will readily become poisoned by the lead; and this objection also applies, in a less degree, in the case of zinc cisterns. Iron is

likewise not free from objection, unless covered with some suitable protective material. Slate, especially if enamelled, is probably the best material for cisterns, though there is some difficulty in making the joints permanently watertight, and therefore such cisterns should always have a proper safe or tray beneath them to prevent leakage from soaking into the building beneath. Every cistern ought to be so placed as to be easily accessible for the purpose of inspection and periodical cleansing, which ought to be done at intervals of not more than about three months. In order that this cleansing of the cistern may be effectually done it is necessary that there should be ample means for the admission of light to it; but the water in a cistern or tank should not be constantly exposed to light, as this would tend to encourage algoid growth in the water. It ought also to be covered over in order to prevent dust, leaves, and other substances, as well as mice, small birds and insects, from getting in; and should likewise be well ventilated, and protected from extremes of temperature. Special precautions should be taken if the cistern is placed in a position where the water in it may be expected to freeze in cold weather, as the expansion of the water when frozen may lead to the joints of the cistern being damaged and result in much inconvenience when a thaw sets in. Unless the cistern is protected in some way, it should be made with sloping sides, the top being wider than the bottom in order to allow the water, in the process of freezing, to expand upwards without exercising much pressure on the sides.

For the purpose of facilitating repairs to the cistern or to the service-pipes leading therefrom, without arresting the distribution of water about the house, it is often useful to arrange the cistern in two compartments, one feeding the other and both connected with the service-pipes, but fitted with stop-cocks so that the service-pipes could draw their supply from either of the compartments while the other was temporarily emptied for repairs, cleansing, &c. So also the service-pipes would, in that case, be capable of being shut off from the cistern by means of the stop-cocks and be emptied for repair or for replacing a defective draw-off tap, or on the approach of very cold weather, when the water in the pipes might be expected to freeze.

It must always be borne in mind that the water-supply to the water-closets of a house must not be direct from the main supply-pipe, or from any of the storage cisterns supplying water used for dietetic and domestic purposes. Numerous instances are recorded showing that outbreaks of enteric or typhoid fever have resulted from supplying water to water-closets direct from the water main, instead of through the intervention of a cistern. Under such circumstances, any intentional or unavoidable intermission of the water-service facilitates and ensures the forcible suction of foul air, and, at times, even other matters, into the mains of the water-service. Hence service-cisterns ought to be provided, in order to ensure a complete break between the basin of a water-closet and the water-main; and inasmuch as, even where such a cistern is provided, there still remains a tendency for the escape of foul air from the basin of the closet up the service-pipe and through the body of water in the cistern itself, thus leading to contamination of the water, a special cistern is necessary exclusively for the water-closet, and what is known as a water waste-preventing cistern, similar in principle to what is commonly required by the water companies, answers the purpose efficiently.

It may be useful here to refer briefly to certain objections to the intermittent system of water-supply—objections which apply equally to cases where the so-called constant supply is in use, but, from scarcity of water during periods of drought or otherwise, not continuously in operation. It has on

several occasions happened that, under such circumstances, the suction into the pipes has been such that various contaminating matters, as foul air, sewage and fæcal matter, blood from slaughter-houses, &c., have been drawn into the pipes, and subsequently distributed in the water, with the result that fever was produced in the neighbourhood.

For the distribution of water about the dwelling lead pipes are usually adopted; but as certain waters act upon any lead with which they may come in contact and become poisoned, it would be better if pipes of some other material were adopted. But there are so many advantages in the use of lead pipes, and the evil results, where the water is not allowed to remain long in them, are so rarely serious, that it is almost useless at present to urge the adoption of other pipes. Tin pipes, or tin-lined leaden pipes, however, have in some instances been used with much advantage.

Turning now to the consideration of the several classes of dwellings above enumerated, we come *first* to the class of mansions and palatial residences of the rich, and perhaps there is less to be said about them hygienically than about any of the other classes, partly because they are usually constructed under the exceptional advantages of liberal expenditure and good professional advice, partly also because, as regards air-space both within and without, there is usually much less necessity for stint than in the case of dwellings of the other classes, and partly because they are not always in full occupation. There are, nevertheless, some points about even this class of house, both ancient and modern, that need more attention than is often bestowed upon them, and indeed instances are not wanting to show that grave defects have been allowed to exist in some old mansions, or to be created in some new ones, which have resulted in more or less serious effect upon the inhabitants, sometimes affecting the servants, sometimes the visitors, and sometimes the members of the family owning and occupying the mansion. These defects have been apparent mainly in the matter of the drainage or sewerage arrangement, though the imperfections of water-closets, and the absence of any sort of disconnection between the interior of the house and the drains, have also, in many instances, come to be known as the direct cause of disease. There are, however, certain other defects common in the class of house referred to that may have a considerable influence on the health of the inmates. That they are in some instances unduly crowded on area, especially in the case of mansions situated in the metropolis, can hardly be denied: for in such cases it is common to find the building covering the entire area of the site, while one or more small courts or wells, intended for light and air, descend in the middle from the top as far as the roof of the ground storey, where skylights alone afford to the rooms and offices below them such poor supply of light and ventilation as may chance to be available, and windows around this well of stagnant air are supposed to suffice for a number of rooms, &c., abutting upon it. Inasmuch, however, as these houses are commonly more or less empty during the greater part of every year, and are only fully occupied during a short season of annual festivity, this defect, which in the case of an institution always occupied to its full capacity would be most serious, can hardly be said to apply.

There is a curious instance of a design for a mansion on what may be called the pavilion system. A celebrated architect, John Thorpe, who lived in the time of Queen Elizabeth, and who designed and carried out many mansions and palaces at that period, has left an interesting design for a house for himself, but which was not erected. This design is preserved in Sir John Soane's museum in Lincoln's Inn Fields, and is in the form of his own initial letters I and T, the portion of the building comprised in the letter I containing

the kitchen offices and servants' quarters, and that comprised in the letter T containing the principal rooms and residential apartments of the house, the two letters being joined together by means of a one-storey connecting corridor. The author of the design facetiously explains it in the following doggerel rhyme:—

Thes 2 letters I and T
ioyned together as you see
Is ment for a dwelling house
for mee
John Thorpe.

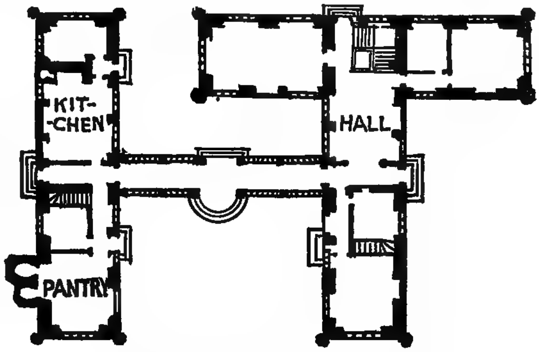


Fig. 115.—Plan of John Thorpe's house.

Although Thorpe's prime object was no doubt to arrange his plan in the form of his own initial letters, there was considerable advantage in the effectual separation of the culinary department from the main residential portion of the house; but, even if this idea formed a basis for the arrangement, it was only partially adopted, since the upper storeys of the portion comprising the letter I appear to have been intended for residential apartments, probably for the servants.

One of the chief sanitary defects in old mansions is the method of disposal of the sewage. In the country this has generally been conveyed first into subsiding tanks or cesspools and then into some lake or ornamental piece of water, or into some stream or river. In towns and in the metropolis this use of cesspools has been very largely resorted to before the liquid has been allowed to flow into the sewers or directly into the river. These conditions still exist in the case of very many large mansions, notwithstanding that the arrangements described are directly prohibited by modern Acts of Parliament, and that the owners of such mansions are frequently themselves members of one or other of the Houses of Legislature, or are otherwise concerned in the making and administration of the laws of the land. Here and there, where grave insanitary conditions have been discovered or where illness or perhaps death has resulted from these conditions, remedies or improvements have been effected; but these would seem to be but comparatively isolated instances. It was only after severe illness in the house that the site upon which Marlborough House stands was discovered to be dotted about with old cesspools and traversed by old drains, the very existence of which was unknown, but which served to saturate the ground beneath the house with filth. This discovery, in 1877, naturally led to very extensive and costly works, comprising the removal of all the old cesspools and drains as well as the contaminated earth, the construction of a new system of drains external to the house, and the covering of the ground-surface within the house with a layer of Portland cement concrete.[1] Again, in this class of house grave results have repeatedly arisen from the position and construction of the water-closet practically necessitating the drains being brought close up to, or even within, the bedrooms and private apartments of the household, the closet itself having no independent ventilation, and constantly delivering subtle poisons into the inhabited rooms. So, too, the domestic offices, larders, pantries, and dairies have been found to be placed

[1] The *Builder*, 1877, p. 1251.

where the servants, as well as the food, have been exposed to the effects, not merely of bad drainage arrangements, but of air that has been vitiated in various ways, perhaps most often by damp and other exhalations from the ground. While in many old houses of this class the defective and unwholesome arrangements above described are allowed to remain undisturbed, on account of the wholesale character of the alterations that would be necessary were they to be remedied, it must be admitted that, in those mansions of quite recent construction, the more obvious defects, at any rate, have generally been carefully avoided.

As regards the *second* class of dwellings referred to at page 658, the suburban and country house of the ordinary professional man of business and wealthy tradesman, the parsonage or vicarage, and the better kind of farmhouse—these are far more numerous than the dwellings comprised in the first class, and in many respects they may be said to contain the same general characteristics as the latter, but in a somewhat modified form. In a vast number of instances the same kind of defects may be found in this class of house as in the first class, but in the main the houses in the second class are, with the exceptions referred to, fairly well adapted to their purposes. There are, however, some features about them that must be briefly referred to, such as the circumstance that they are usually more permanently occupied than the palatial mansions, and accordingly any defect is more likely to produce more intense effect than where the dwelling is allowed to remain empty for a certain period every year. Then, again, in this kind of dwelling the inferior apartments, such as the bedrooms set apart for servants, are often so placed and constructed as to be indifferently warmed and ventilated, or so as to be readily affected by external temperature, or they are placed in undue proximity to the domestic offices, stables, &c., and so that the smell from these places is never absent from the apartments.

In the case of vicarages and rectories, the fact of their being periodically overhauled by officers of the Ecclesiastical Commissioners or the Diocesan Surveyor, whenever there is a change of the incumbency, leads to their being generally kept pretty well up to date in regard to most of the ordinary hygienic requirements, while, as regards new parsonages, they have to be erected in conformity with the somewhat stringent requirements of the Ecclesiastical Commissioners, and although these may not always be as complete and effectual as the hygienist would desire, they are, nevertheless, very useful in securing substantial construction on sound general principles.

The *third* class of dwellings to which reference has been made involves certain difficulties of arrangement which are seldom met with in connection with the two preceding classes of dwellings. With this class, which is more urban in character than the country-house already referred to, commences the embryo of that important question of adequacy of open space about the dwelling, both to the front and to the rear, in order to ensure facilities for free circulation of air about the house and opportunity of ventilating the interior. Owing to the greater value of land in the urban district than in the open country, this difficulty increases in proportion as the dwelling is nearer to the centre of the urban district, where, owing to the exigencies of population, trade, and business, the houses are necessarily packed somewhat closely together and built of great height. Indeed, every new building that is erected on the site of an old one is often made fully twice as high as its predecessor. To such an extent is this the case in some localities that dwellings have to be piled one on the top of another, many storeys in height, under the same roof, under the modern denomination of 'flats.' Accordingly, under

this head are comprised the ordinary detached and semi-detached house of moderate size, and the terrace-house, or house in a row of attached houses of indefinite length, of size and value varying from the ten- or twelve-roomed house, of a rental of some sixty or seventy pounds a year, to the town-house of two or three times that size and eight or ten times the rental value, situated in the best residential streets at the West-end of the metropolis and of the provincial towns. The system of flats, which is a modern innovation from the Continent, possesses many advantages, when well carried out, over certain classes of houses for the middle classes in the ordinary streets of London and other towns. It may be described as that of laying the ordinary tall house down horizontally. Such a house obviously occupies a larger area than the same accommodation arranged vertically in the one house of some six or seven storeys; but, on the other hand, the entire block of flats may be several storeys high, and at least as many sets of flats or dwellings can be arranged on the same area. It would also be possible to arrange the several dwellings in various sizes to suit the requirements of different tenants. The advantage gained by throwing the several small backyards separated by the party fence walls that would have to be provided behind the row of tall narrow houses, into one undivided yard of considerable length would alone be considerable, while if, in the case of a site lying between two streets, the courtyards were arranged to communicate with the streets by means of clear openings or large archways, the advantages as regards circulation of air would be greatly increased. As an indication of this latter arrangement an excellent plan,[1] designed by Mr. William H. White, F.R.I.B.A., was laid before the Royal Institute of British Architects in 1877, showing how the block of twenty-eight London shops and dwellings lying between Regent Street and Warwick Street on their west and east, and Beak Street and Regent Place on their north and south, have from time to time been altered and intermingled, until they have become only twenty in number, and practically the entire area has been gradually covered with building, for only four or five very small well-holes remain open for light and air, the frontages of the buildings extending continuously all round the site. By the rearrangement and reconstruction of the buildings on this 'island,' Mr. White shows that as many as twenty-one shops and nineteen good and roomy houses might be constructed upon it, while the courtyards would be such as would ensure free circulation of air and ample light. One important feature that appears requisite to bear in mind in the case of a block of dwellings arranged as 'flats' is the advisability, in the interests of health, of so arranging the common staircase or staircases that, if they are not open to the external air, they shall at least be capable of good through-ventilation by opposite external windows. This would be of special advantage as tending to prevent the spread of infection in the event of any dangerous infectious disease occurring in any dwelling in the block.

The kind of dwelling comprised within the *fourth* class above alluded to —namely the dwelling in connection with the place of business, the hotel, inn, &c.—is very numerous, and includes not only the ordinary ten- or twelve-roomed house with a shop in the ground storey, but the large drapery establishments and other commercial houses where the upper part is devoted to apartments for the numerous employés of both sexes engaged in the service of the establishment, and who in some instances are many hundreds in number. In this sort of dwelling the question of open air space about the house is often involved in much difficulty, for the chief value of the premises

[1] Illustrated and described in the *Transactions of the R.I.B.A.*, and also in *Our Homes*. London: Cassell & Co., 1883.

lies in their capacity for the purposes of business, and accordingly the superficial area available for shop purposes in the ground storey—or more particularly at the street level—with such additional space for showrooms, warerooms, and the like, in immediate connection with the shop, constitutes the chief element in the value of the premises from the purely business point of view. Hence everything is sacrificed to increasing the area available for business requirements, and unless some control be exercised over the arrangements, the health conditions of the premises are undoubtedly prejudiced. Thus in all such cases the first effort is to secure the largest area possible for the shop, and accordingly this is extended over the entire area of the site from front to rear boundary, so as to preclude the possibility of forming any sort of yard at the ground level where the necessary ashpit or dustbin may be put, and so as to exclude all means of lighting and ventilating the basement storey, except from a sort of shallow area beneath the shop window in front. Sometimes palliatives for these defects are provided in the shape of reflectors for light and air-shafts for ventilation; but these, as a general rule, hopelessly fail to effect their purpose to the necessary extent, since gas or other artificial light has often to be constantly used, and the ventilation of the basement is left to take care of itself; and this notwithstanding that dozens of young men and women may be employed in this storey during many consecutive hours from morning till evening. Nor is this all: it is not uncommon to find in this artificially lighted and imperfectly ventilated basement the closet, urinal, and lavatory accommodation for certain of the employés, which is merely screened off, so to speak, from the main apartment, and is utterly incapable of being maintained in a proper and wholesome condition, however well it may be kept by those servants immediately responsible for its cleanliness.

In the shop itself the ventilation mainly relied upon is generally the front doorway, which is kept open for customers as much as possible, and some skylights having a small portion to open, over the rear portion of the shop; but this is rarely sufficient to keep the air within it even moderately pure. The quantity of gas frequently consumed in large shops, the ascent of vitiated air by the stairs from the wareroom or offices in the basement, the exhalations from the large numbers of employés and from customers, as well as the emanations from the clothes of the latter, particularly in wet or warm weather, and the dust, particles of fibre, and smell from the stock and goods in the shop, all combine to render the atmosphere unwholesome. Add to this the conditions of fatigue, posture, long hours, &c., under which the employés have to perform their work, and it will be seen that the conditions are often far from satisfactory. It further frequently happens that the sleeping apartments of the employés are so placed in the house above the shop and showrooms that the products of combustion of gas and the other deleterious conditions of the air in the shop are easily conveyed by ill-ventilated staircase and passages to the upper storeys, and thus contaminate the air in which the employés pass the night. There are many establishments where these defects, if they exist at all, have been reduced to a minimum—where the whole condition, hygienically, mentally, morally, and physically, of the employés is the constant care of the principal and his higher staff—but there are also numerous others where a very cursory inspection will demonstrate the necessity for improvement, while in the case of the erection anew of such establishments it ought not to be difficult to so contrive them as to obviate most of the defects referred to. There is, however, one further point affecting the hygienic conditions of such establishments to which attention should be directed, and this is the amount of closet accommodation that is requisite for the employés of each

sex. In some instances it has been found wholly inadequate to the numbers employed, the number of the latter having increased with the extension of business; in other instances it has been found to be so arranged as to be not readily available, or to be so improperly separated, that for one sex from that for the other sex, as to tend to prevent that regular use of these conveniences which is essential to health.

The hotel, inn, public-house, restaurant, and other dwellings of that character, undoubtedly demand more serious attention from a hygienic point of view than they have perhaps hitherto generally received. In the modern palatial hotel much has been done to avoid many of the defects that are common in the old-fashioned hotels, though even here defects of want of light and air consequent upon the effort to crowd too much building upon area are of too frequent occurrence. But all who have occasion to stay at the old-fashioned family and commercial hotel or inn, especially in the older cathedral towns and in most market towns, will be intimately acquainted with the close, fusty atmosphere within its walls. At night, on retiring to his bedroom, the visitor will find it impossible to escape the smell of cooking and the odours from the bar-parlour, together with the products of combustion from the numerous gaslights and lamps. On opening his bedroom door in the morning to take in his boots and hot water, he will encounter the strong smell of fried bacon, fish, coffee, and other preparations for breakfast; and he will be fortunate if, during or after his stay in the hotel, he do not suffer from the effects of defective or obsolete forms of water-closet arrangement and fittings, the ill-contrived chamber-maid's slop-sink, and the badly arranged and rarely cleaned cistern in near proximity to his apartment. To the casual visitor these objectionable conditions may perhaps be of comparatively small moment, but to the numerous servants who pass their whole time on the premises, night after night and day after day, the effect is probably more serious, and goes far to account for the pallor and sallowness of complexion so commonly met with among this class of servants, who, moreover, frequently occupy only indifferent apartments and have very poor accommodation,[1] barely complying with rules that would ordinarily be laid down for the prevention of overcrowding. In a certain class of modern hotel, where convenience of detail has been sacrificed to external appearances, the size of the windows is so large, and indeed out of all proportion to the size of the rooms, that much difficulty is experienced in opening them, and consequently there is a tendency to keep them permanently shut; a tendency which is encouraged by the chamber-maid's desire to prevent the entry of dust and soot, with which the atmosphere of our larger towns, such as Birmingham, Manchester, Sheffield, Leeds, &c., is so loaded.

The *fifth class*, concerning as it does the millions, is necessarily the most numerous of any class of separate dwelling. It is, moreover, the class that may be said to call for more control and supervision than any other class of dwelling, since the comparatively small cost of each dwelling affords a larger scope for building speculation than in the case of more costly dwellings. At the same time it must be admitted that a vast amount of good has been, and is still being, done by philanthropic individuals and societies to provide wholesome and decent dwellings for this large class of the community, both in town and country. In this respect the wage-earning classes are more fortunate than that stratum of the lower middle class, which is composed of persons who earn, as yearly salary or income, scarcely more than is paid in

[1] An instance has come under the notice of the writer where in a well-known and reputable tavern-hotel the night porter occupied by day the same bed that a lad in the service of the hotel occupied by night.

weekly wage to many a jobbing mechanic, but who is nevertheless obliged to keep up some appearance of gentility. For while the artizan and mechanic can choose a dwelling either in a sort of town of well-built houses, or in a block of so-called 'industrial dwellings,' specially erected for his class under the competent professional supervision furnished by the aid of some admirably administered building society or philanthropic association formed for the special purpose of providing cheap and good houses for this class, the clerk, the draughtsman, the poor clergyman, and a host of others of that class, are obliged to seek a house among those erected almost exclusively by speculating builders, with only indifferent supervision, and the majority of which have been built under no sort of skilled professional advice whatever. There are, it is true, many dwellings, modern as well as old, occupied by the wage-earning community which from various causes are sadly defective in some of the most important features of good hygienic arrangement, but, as a general rule, an amount of professional skill, both medical and architectural, is nowadays brought to bear upon the modern artizan's dwelling which is leading to enormous improvements in construction and arrangement. This is partly due to the general progress of sanitary knowledge as regards details of construction, and, in its larger bearing, to the various Acts of Parliament which have been passed by the Legislature in obedience to the demands of public opinion for increased facilities for effectually dealing with so important a subject. As regards the latter, some improvement has unquestionably resulted from the application, during the period between 1870 and 1890, of what were popularly known as Torrens's Acts [1] and Cross's Acts.[2] Some earlier Acts for similar purposes, known as Shaftesbury's Acts, had been passed as long ago as 1851, but these had never been put into operation, and remained always a dead letter. All those Acts applied mainly to London and to certain urban districts in the provinces. Torrens's and Cross's Acts, however, were found to involve serious cost and such cumbersome and slow proceedings that numerous instances arose where, notwithstanding urgent need for improvement, it was found almost impossible to apply them. Accordingly, the Housing of the Working Classes Act, 1890 (53 and 54 Vict. cap. 70) was passed, in order to consolidate the laws and to simplify the procedure which had to be taken under the previous Acts, and under this new Act the powers of improvement have been extended to rural sanitary districts, where the local authorities are to exercise them, under the supervision of the County Councils.

The provision of healthy and convenient dwellings for the wage-earning community has exercised the attention and ingenuity of philanthropists and others in our own country as well as in certain foreign countries for now nearly half a century. In England shortly after the constitution of the Poor-law Commission in 1834, following as this did soon after the first visitation of epidemic cholera to this country in the year 1832, the subject of the sanitary condition of the labouring classes attracted much attention owing in a great measure to the statements made in the early annual reports of the Commissioners as to the prevalence of disease among those classes;

[1] Mr. Torrens's Acts comprise the following, viz. 31 & 32 Vict. c. 130 (The Artizans and Labourers' Dwellings Act, 1868); 42 & 43 Vict. c. 64 (The Artizans and Labourers' Dwellings Act (1868) Amendment Act, 1879); 43 Vict. c. 8; and Part II. of 45 & 46 Vict. c. 54 (The Artizans' Dwellings Act, 1882).

[2] Sir Richard Cross's Acts comprise the following: viz. 38 & 39 Vict. c. 36 (The Artizans and Labourers' Dwellings Improvement Act, 1875); 42 & 43 Vict. c. 63 (The Artizans and Labourers' Dwellings Improvement Act, 1879); and Part I. of 45 & 46 Vict. c. 54 (The Artizans' Dwellings Act, 1882).

and in 1842 an important report upon the whole subject compiled by their secretary, the late Mr., afterwards Sir, Edwin Chadwick, K.C.B., was issued. The press took up the subject, and notably the 'Builder,' under the able editorship of the late Mr. George Godwin, F.R.S., kept the matter well before the public, losing no opportunity of describing the grave sanitary state of dwellings generally, and those of the poor in particular, and of advocating reform and improvement. In 1844 a society, having the late Prince Consort as president, was formed for improving the condition of the labouring classes, their prime object being to provide, either by alteration or adaptation, suitable dwellings for those classes. In 1851 this society erected at the International Exhibition in Hyde Park an excellent model block of four dwellings which was subsequently re-erected at Kennington, where it may still be seen. Other societies, such as the Industrial Dwellings Company, of which Sir Sydney H. Waterlow is chairman,[1] and the Artizans', Labourers', and General Dwellings Company have since been formed for providing suitable dwellings for the wage-earning classes, and the trustees of the funds provided by the munificence of the late Mr. Peabody have also, since 1862, when they commenced, done much for providing improved dwellings for these classes in the metropolis. In the provinces various large employers of labour have made great efforts to provide their employés and others with good dwellings: this is especially the case at Saltaire, near Bradford, where a very complete town has been provided by the late Sir Titus Salt. This town includes, besides dwellings for several hundred workpeople, a church, schools, lecture-room, library, baths and washhouses, &c. At Akroydon, near Halifax, a somewhat similar village has been constructed under the auspices of Mr. Edward Akroyd in conjunction with the Halifax Permanent Benefit Building Society; and at West Hill Park, Halifax, a similar scheme has been carried out by the co-operation of the landowner (the late Sir John Crossley) and the Building Society, under which the workman may become the owner of a well-built, wholesome house on very advantageous terms. At Liverpool, Barrow-in-Furness, Newcastle-on-Tyne, and other busy manufacturing towns, much has been done in a similar way for the better housing of the labouring classes.

On the Continent corresponding efforts were made for the same object. In Paris the Emperor Napoleon III., while President of the Republic, caused to be erected, in 1849, what was called a *cité ouvrière*—a huge barrack, situated in the Rue Rochechouart—a scheme, however, which did not prove very successful in any way, as the workpeople disliked being *caserné*, or barracked. In 1852 a sum of ten million francs was allotted by the Government for the amelioration of the labourers in the great manufacturing cities of France, and with this money various improvements were effected in their dwellings. At Mulhouse (Alsace), Mons. Jean Dolfus, an eminent manufacturer, and at the time mayor of the town, started in 1853 a company, under the title of the Société des Cités Ouvrières, with a capital of 300,000 francs; but as the system of housing the working classes in these vast 'barracks' proved very distasteful here as at Paris, it was unanimously rejected by the Committee at Mulhouse in favour of a system of detached blocks of four houses, mostly two storeys high, besides cellar and attic. This *Arbeiterstadt*, or artizans' colony, now comprises upwards of 1,000 houses,

[1] In the evidence of Sir Sydney Waterlow before the Royal Commission on the Housing of the Working Classes (1884) it is stated (Q. 11,909) that this company alone had then erected 4,314 tenements, accommodating 22,000 persons, while 665 additional tenements for 3,000 persons were in course of erection, the average rent per room being 2*s.* $1\frac{1}{4}$*d.* per week, which included rates, taxes, repairs and lighting of passages, and proper maintenance.

each containing one or two families and provided with its own small garden. There are likewise a large bath-house and washing-house, school for infants, &c. The houses are said to have cost from 120*l.* to 150*l.*; each and nearly all have been sold to the workmen themselves at a very slight profit, the purchase money being repaid by instalments. Similar schemes were carried out about the same time at Gebweiler and at Beaucourt and elsewhere in France. The late Mr. George Godwin, F.R.S., one of the Royal Commissioners for inquiring into the housing of the working classes, in 1884, in a memorandum appended to their report, after referring to the fact that advantageous arrangements for housing the working classes by some of the large employers are made abroad, describes what is known as the *familistère* in connection with the establishment of M. Godin-Lemaire at Guise, near St. Quintin, in France, for the manufacture of stoves and ranges. The workmen—700 or 800 in number—and their families are here housed in flats, three or four storeys high: nurseries for infants, and schools for the children as they grow up, are provided, and the whole is stated to have been carried on satisfactorily and profitably for about twenty-five years. There has thus been a growing tendency in England and France at any rate to provide improved dwellings for the labouring classes in the more populous areas, and this tendency has extended into Belgium and certain parts of Germany. As regards the provision of improved dwellings for the labouring classes in the rural districts of the United Kingdom, this, where it has been undertaken systematically, has been done mainly by the landowners, and, to their credit be it said, the owners of extensive domains in the country have put up some excellent cottages for their workpeople. The Land Commissioners have issued a number of sheets of plans for farm labourers' cottages which afford some excellent hints as to suitable arrangement with strict regard to economy, some of which are shown in figs. 116 to 124.

The cottage ordinarily provided for the agricultural labourer is generally semi or wholly detached, since they are usually scattered about the estate. Rows of cottages are less frequently erected for this class than for the artizan classes, who have to be concentrated in more close proximity to their work. The labourer's cottage ought to comprise a living room with small scullery attached and at least three bedrooms, one for the parents and two for the children. The most economical arrangement of this accommodation is in a two-storey building, and in that case the lower storey should have a clear height between floor and ceiling of at least nine feet and the upper storey not less than eight feet. The living room being the principal one, and the one to be used by all the inhabitants in common, ought to be as large and commodious as practicable, with a minimum floor area of 150 square feet. In this room should be a good cupboard, lighted and ventilated by a separate window, so that certain articles of food may be kept in it without affecting, or being affected by, the air of the room itself. The scullery adjoining the living room should contain a copper with furnace, and sometimes also a bread oven, likewise a sink, plate-rack, &c. Convenient minimum dimensions for this room are 10 feet by 7 feet 6 inches. The pantry can be entered through the scullery, but must have independent ventilation direct to the external air. On no account should it be placed in an underground cellar, nor in the staircase leading up from the cellar. It is important that the pantry should be open to free ventilation, light, cool and dry, and, above all, well protected against the rise of ground air. The fuel stove is best placed in a shed out of doors —where also should be the necessary privy accommodation and place for temporary deposit of dust and house refuse. The staircase should be so arranged as to obviate the possibility of its serving also as an air-shaft

up which the vitiated air from the living room could ascend to the sleeping apartments. This is most effectually secured when the living room is entered through an enclosed porch, which likewise gives access to the stairs, as in fig. 121. The provision of an adequate porch has the further advantage of affording the entrance some protection from the weather, while it is always useful to the occupier as a place for removal of outer clothing, boots, &c., in wet weather instead of taking them direct into the living room. The bedrooms ought to be as large as the circumstances permit, that for the parents being about 12 feet by 10 feet and provided with a fireplace and good cupboard; and the children's rooms having a floor area of about 80 square feet and 50 square feet respectively; and it is very desirable that these rooms should have fireplaces in them.

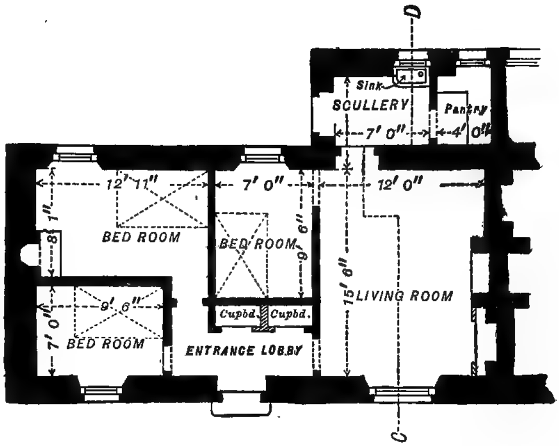


FIG. 116.

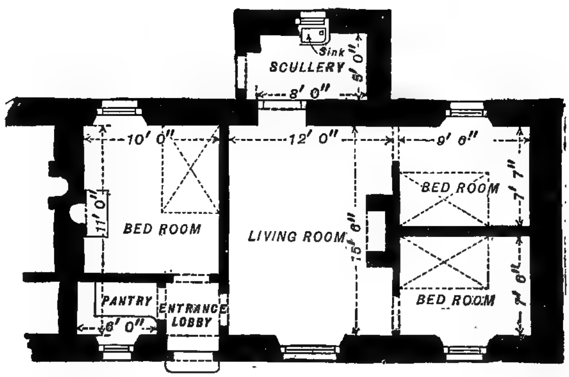


FIG. 117.

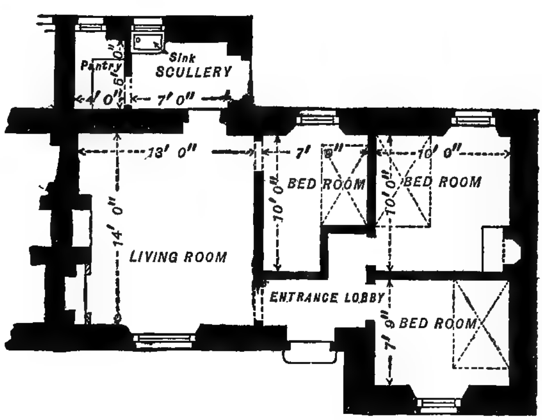


FIG. 118.

Approximately the same accommodation as last above described may be obtained in a one-storey cottage arranged upon either of the plans (figs. 116 to 120).

The artizan's dwelling involves greater difficulty of arrangement upon a convenient, adequate, and wholesome plan than the agricultural labourer's cottage, since it is usually necessary to place it on a site where land itself is of much greater value than agricultural land. It has to be in the immediate vicinity of some factory, where considerable numbers of persons are employed, and therefore, if not actually in a town, it must be in at least a populous district. Hence, the necessity for

crowding the dwellings together; and so great is this necessity that, not only are the dwellings often arranged in rows with streets of the minimum width permissible in the locality in front of them, and with the smallest permissible amount of open space at the rear of them, but in many towns and in the metropolis, where the cheapest land is very costly for the purpose, the houses have to be piled up in blocks of building many storeys in height. The separate house of the artizan usually built in rows in the suburbs of the busy manufacturing towns differs but little, as regards accommodation, from the dwelling of the country labourer with a family, but the modern block of artizans' dwellings that has developed in the last fifty years involves some important hygienic questions that can scarcely be said to apply in the case of separate dwellings. This type of building has undergone much change, and many hygienic improvements have been made in the more recently erected blocks of dwellings.

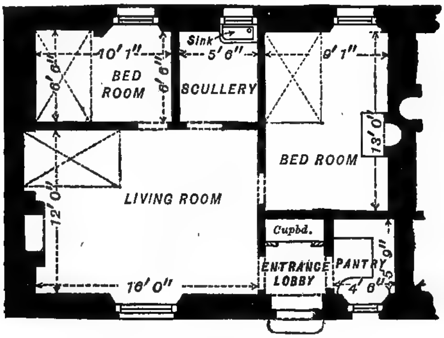


FIG. 119.

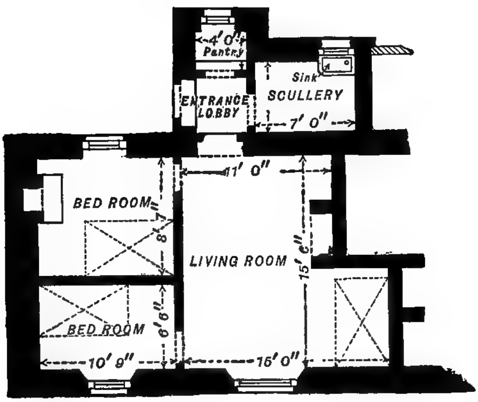


FIG. 120.

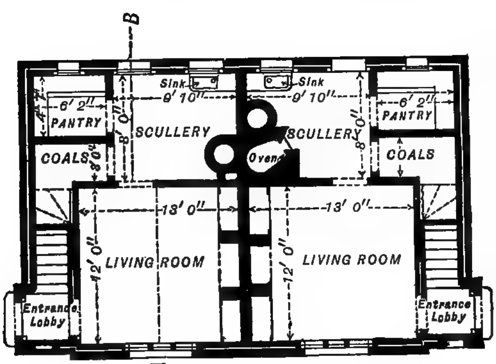


FIG. 121.

In what is probably the first published plan for such a building, designed, in 1841, by Mr. Sydney Smirke,[1] a number of separate dwellings consisting of one, two, or more rooms each, are arranged along both sides of a main corridor eight feet wide in each storey of a three-storey building planned in the form of the letter E. A similar arrangement of dwellings along both sides of a corridor was adopted in some of the earlier blocks of building erected by the trustees of the Peabody Fund. This plan, however,

[1] *Report by the Poor-law Commissioners on the Sanitary Condition of the Labouring Population of Great Britain*, p. 274. Prepared by Edwin Chadwick. London: 1842.

has now been discarded owing partly to the dislike evinced by the inhabitants of the dwellings to the absence of privacy and independence that was inevitable under the corridor arrangement, and partly to hygienic objections. As regards the latter, the corridor always involves much difficulty in regard to light and ventilation; it interferes with the through-ventilation of the dwellings along its sides; it leads to the enclosed atmosphere of the whole building being uniformly vitiated by the aggregation of a large population, and in the event of any infectious disease occurring among the inhabitants of one dwelling, the risk of its spreading, by means of the corridor and staircases, to the inmates of the other dwellings in the same building is very considerable. A further defect in the earlier blocks of dwellings was the provision of a water-closet as an integral part of each dwelling, and arranged in such relationship to the rooms as to be more or less a source of danger to health. The disposition of the blocks on the site available for them was a further point upon which many errors have been made, for in some instances the blocks, many storeys high, have been directly connected together at a right angle, and even at an acute angle, so as to seriously interfere with the free circulation of air about the exterior and the access of light to many of the rooms. In some instances the buildings have been arranged continuously round a central courtyard with a mere archway, one or two storeys high, in one side to give access thereto. These grave defects,

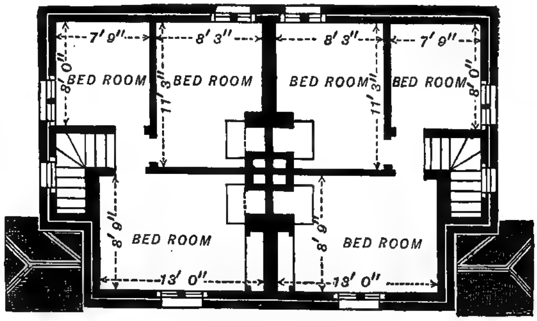


FIG. 122.

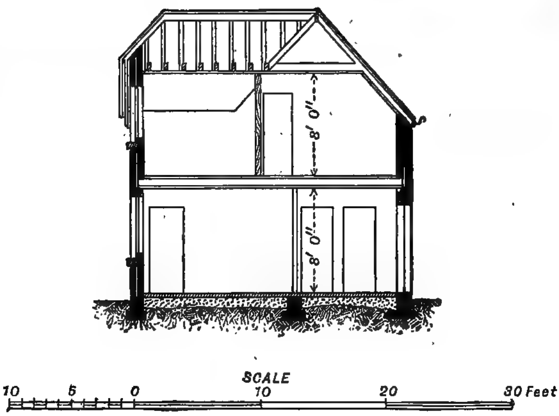


FIG. 123.

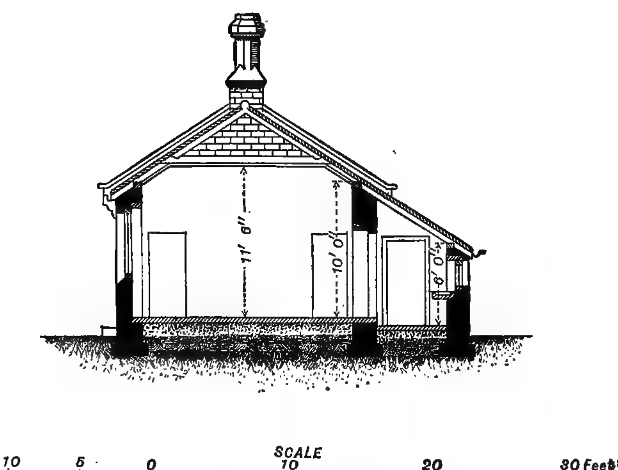


FIG. 124.

which have been found prejudicial to the health of the inhabitants, and to increase the death-rate, especially the infant mortality, have been generally much diminished in the more recently erected blocks of dwellings. The corridors have been dispensed with, and each dwelling is now usually independent of the others, so far as enclosed atmosphere common to all is concerned; for the staircases are generally arranged to give access to one vertical series of dwellings only on each side of them, and are entirely open to the external air. The water-closet accommodation to each dwelling is often arranged so as to be accessible from the external air by means of some sort of balcony; and the blocks of building are often wholly detached, thus doing away with confined angles and stagnant corners. These improved arrangements, however, are not invariably adopted, and unless some controlling authority is invested with power to require them, and to see them carried out, it seems probable that the natural desire to provide numerous cheap dwellings, at the smallest possible outlay, will induce many speculating builders and others to still erect huge blocks of dwellings, piled up storey upon storey, regardless of light and air, and producing an excessive aggregation of human beings under the one roof and an undue density of population on area. This has already been referred to; hence it is only necessary here to point out the extreme necessity for insisting upon ample open space between the blocks of these dwellings, and the complete disconnection of the blocks one from another, in order to avoid all confined angles and to ensure the utmost freedom of circulation of air about the blocks, and of access of light with a certain amount of such sunshine as is available in our climate to every room intended for habitation during a portion of the day. If these conditions are insisted upon, *culs-de-sac* will in effect be prohibited, and the height of the blocks on the one hand, and the distances between them and adjacent buildings or blocks on the other, will have to bear some relation the one to the other.

Much credit is often assumed by certain managers and directors of existing dwellings of the kind referred to for the moderate death-rate and rate of infant mortality in the dwellings, and it is sought to illustrate the excellence of the health arrangements of the respective blocks of dwellings by a comparison with the rates of mortality of the metropolis as a whole. But it has to be borne in mind that the occupiers of these blocks of dwellings are, to a very large extent, a population specially selected for their respectability and other good qualities. It is generally admitted that these inhabitants are always socially far above the class of inhabitants of the insanitary dwellings that were pulled down to make way for the improved dwellings, that the landlords of these new dwellings naturally drift into the groove followed by all landlords and get rid of the worst tenants, and thus the inhabitants of these dwellings come to be a picked set of highly respectable families. With all this in favour of the health conditions of the population of these dwellings, the difference between the mortality rate in them and in the whole metropolis is often but very little, especially in regard to the rate of infant mortality. Thus it is stated, for example, that in a population of between 6,000 and 7,000, occupying upwards of a dozen different estates of such dwellings—though there was room for more, many of the dwellings being empty—the general death-rate was only 15·6 per 1,000, while in the whole metropolis it was 18·5; but in these same dwellings the rate of infant mortality was 140 per 1,000 births, or only six less than in the whole metropolis, where the rate during the same period was 146 per 1,000 births. This difference in so important a matter as infant mortality seems much smaller than should be regarded as completely satisfactory.

There are many points about the dwellings of the artizan and labouring

classes which, even where they have been erected otherwise than by mere speculators, call for special attention and improvement. The customs of the people and the character of the locality, moreover, often exercise a certain influence upon the hygienic arrangements, for whereas in southern towns of England water-closets are almost universal in dwellings of the class under consideration, similar dwellings in the midlands and in the northern counties are frequently provided with some sort of privy or dry system of closet. It is not at all uncommon, too, in the latter districts to find the amount of closet or privy accommodation in much smaller proportion than in the south, and such as is provided is often arranged in what would be regarded in the more southerly districts as very inconvenient positions relatively to the houses for which they are intended. The Public Health Act, 1875, in Sec. 35 prohibits the erection of any house ' without a sufficient water-closet, earth-closet, or privy.' But Sec. 36 gives the local authority certain discretion in regard to their judgment of the sufficiency of closet accommodation where a closet or privy has been, is, or may be used in common by the inmates of two or more houses, and accordingly houses for the artizan and labouring classes are sometimes erected, even under the authority of town councils and other local sanitary authorities, which have only one closet to every two, three, and sometimes even four houses, the closets thus provided being placed in groups in one yard common to all the houses in which the children play, the women hang out their linen to dry after washing, and the men and boys loiter about. The objections to these arrangements, quite apart from the question of decency and morals, are serious from a hygienic point of view. Thus the distance of the closet from some of the houses it serves is sometimes excessive—thirty or forty yards—and in some instances so placed that the occupiers of certain houses must come out of their front door, pass along the street to a passage leading through the row of houses to the privies in the common yard at the rear. It will be obvious that such an arrangement must tend to deter the inhabitants from using the closets as freely as might be desired, while it certainly leads to the very objectionable practice of retaining excreta in the houses until a convenient opportunity for carrying them to the privies.[1] The arrangement is further objectionable on sanitary grounds, since it involves the use by the inhabitants of two or three different houses of one privy in common, and since this privy discharges into the same receptacle as do other privies which are resorted to by the inhabitants of other houses. Under such circumstances infectious disease occurring in any one of these houses might possibly be communicated to the inhabitants of the other houses through the medium of these privies and ashpits.

Another grave defect that exists in many cottage dwellings in certain

[1] Mr. Butterfield, formerly Medical Officer of Health for Bradford (Yorks), reports that during an epidemic of summer diarrhœa which prevailed in that town in 1878 certain houses in which deaths had occurred were visited, when it was found that the houses fronting the street had suffered far more from the disease than those next the backyard, in which were situated the privies and ashpits. Mr. Butterfield goes on to say: ' Why the deaths should be twice as numerous in the front houses than in the back ones, which face the privies and ashpits common to both, is not easily accounted for unless the more ready access to the conveniences induces a more frequent and prompt removal of the excreta than is the case in the front houses. I have frequently remarked that, rather than pass through the portions of street and passage necessary to reach the proper receptacle, women will conceal excreta in some obscure corner of the premises until nightfall. The effect of thus contaminating the already sufficiently close atmosphere of a back-to-back house is of course exceedingly prejudicial to a child suffering from the effects of bad nursing and improper diet. More especially is this the case when the obscure corner before mentioned is beneath the shelf on which the milk is kept.'

districts where the land is of a very hilly character is that of erecting on the side of a hill rows of cottages one row directly over the other, the dwellings in the upper row fronting the rise of the hill in one direction and those in the lower row fronting the descent of the hill in the reverse direction, with the result that while the houses in the upper row have at their rear ample air space, though no yards, the houses in the lower row have neither air space nor yard at their rear, which generally abuts against the earth beneath the street or roadway in front of the upper row of houses, and consequently the lower ones are not only unprovided with any effectual means of through-ventilation, but are necessarily dark and damp. Such houses, new as well as old, are to be met with in numbers of towns in the hilly districts of South Wales, Yorkshire, and elsewhere.

For many years past the system of back-to-back house construction has been condemned as being inconsistent with proper hygienic conditions, but it is curious to notice how scanty were the actual reasons upon which this general condemnation was based. True, the prevalence and intensity of sickness in any town where this class of house was at all common were found to be frequently greater in the locality where such houses were most numerous than in other parts of the same town, but then the condition of the surroundings of those houses as well as of the inhabitants themselves was generally sufficient to account in a great measure for the excess of sickness among them. This defective condition of surroundings was no doubt largely due to bad local administration consequent on the then existing rudimentary knowledge of sanitary requirements, upon the absence of efficient laws for the prevention of overcrowding, upon defective systems of drainage, or possibly the total absence of drainage, and upon the unlimited amount of the most repulsive filth and refuse in various stages of putrefaction that was commonly allowed to accumulate within, or in close vicinity of, the dwelling, thus loading the air at all times and under all circumstances with offensive and mischievous effluvia.

Such were the conditions that formerly existed in numbers of towns, particularly in the north of England, where this class of dwelling was prevalent; and under such conditions it followed that the habits of the occupiers of such houses only too frequently from their slovenliness made the interior a counterpart of the exterior. Great improvements in the sanitary administration of towns have taken place in recent years, and the beneficial results therefrom may readily be perceived and are generally freely admitted, but the actual sanitary disadvantages of the system of back-to-back house construction *per se*, while still generally admitted, have not hitherto received that searching investigation which the subject deserves and which is requisite in order to demonstrate the serious prejudicial effect which it is, with good reason, believed to have upon the occupiers of such houses and the district in which those houses are built. That the question deserves serious attention can hardly be denied when its magnitude is taken into account. In many towns this vicious system of house construction is permitted under local Acts of Parliament; in others it is allowed under some obsolete series of building bye-laws; and even in the metropolis, where unfortunately there is but little legislation for the sanitary control of new buildings, it is not prohibited, directly or indirectly, either by Act of Parliament or by bye-laws. Under these circumstances, and seeing that the construction of back-to-back houses tends to the crowding of houses on area, thereby in one sense enhancing the value of building land, it is not surprising to find that the system, in one form or another, has been and is still extensively adopted in many places; and not only so, but in neighbouring

newly developed localities the sanitary authorities are often desirous of adopting the same mode of house construction in order either to conform to what is regarded as a local custom, or that house accommodation may be provided for the wage-earning classes upon the same basis of expenditure and under similar conditions as is provided in the older adjacent district. From statistics published in a recent Government report[1] upon the subject it appears that in the borough of Halifax, where the erection of back-to-back houses is still permitted and controlled by a local Act of Parliament, there were 2,094 dwelling-houses of all kinds erected during the eleven years 1876–86, and of these no less than 1,287, or 61 per cent., were back-to-back houses. In Leeds, again, where a local Act permits and regulates the construction of back-to-back houses, the same statistics show that during the two years ending August 1887, out of a total of 2,311 new dwelling houses of all classes that were certified as fit for habitation, no less than 1,502, or 65 per cent., were of the back-to-back type, and it is estimated that house accommodation of this type had been erected in the municipal district of Leeds during the twelve years ending August 1887 for the large number of 50,000 persons. In Bradford, where the erection of back-to-back houses is likewise allowed and governed by a local Act of Parliament, in the eleven years 1876–86 out of a total of 7,036 new houses, 4,486, or 64 per cent., were built on the back-to-back system—equal to new house accommodation for a population of some 20,000 persons.

In the metropolis it is difficult to arrive at any precise statistics of what is being done in the way of erecting dwellings unprovided with means of through-ventilation, but the various Acts of Parliament which control the erection of buildings in the London district contain no provisions whatever that would have the effect of wholly prohibiting the erection of back-to-back houses. The Metropolitan Building Act, 1855, provides, in Sec. 29, that every dwelling house, 'unless all the rooms can be lighted and ventilated from a street or alley adjoining,' shall have in the rear or on the side thereof an open space exclusively belonging thereto to the extent at least of 100 square feet; and this requirement is supplemented by the requirements of Sec. 14 of the Amendment Act, 1882 (45 Vict. cap. 14), which enacts that every new building to be erected on a site not previously occupied in whole or in part by a building, and intended to be used as a dwelling house, shall, unless the Metropolitan Board of Works (now the London County Council) otherwise permit, have directly attached to it in the rear an open space exclusively belonging to it of an extent varying according to the length of its frontage. Thus if the frontage do not exceed 15 feet in length, an area of at least 150 square feet is to be provided; if the frontage do not exceed 20 feet in length, the extent of the open space at the rear is to be at least 200 square feet; for 30 feet frontage, 300 square feet; and for more than 30 feet frontage, the extent of open space is to be at least 450 square feet. The clause likewise provides that the open space shall extend throughout the entire width of the building, but allows the site to be entirely covered by building in the ground storey.

That these provisions are utterly inadequate to meet the requirements of the present day as regards open space at the rear of dwellings as an indispensable condition to the efficient through-ventilation of such buildings is shown by the fact that numbers of dwellings are continually being erected with insufficient open space at their rear or with no open space at all. The short provisions on the subject in the Act of 1855 were admittedly inadequate, as an extension of those provisions was included in the Amendment Act of 1882;

[1] *Joint Report to the Local Government Board of Dr. F. W. Barry and Mr. P. Gordon Smith on Back-to-Back Houses.* London: Eyre & Spottiswoode, 1888.

but those extensions are so framed as to be of little real use, as they are inapplicable except in the outskirts of the metropolitan area, where alone building sites 'not previously built upon' are to be found; and even these extensions, which may be waived at the discretion of the controlling authority, permit of the erection of a building with a basement storey likely to be used as offices or for habitation to which no direct light could have access, and air could only be got by means of shafts and the like, while the open space at rear would be entirely above the level of the ceiling of the ground storey. The requisite amount of open space, moreover, is to be calculated according to the length of frontage instead of, as it ought to be, according to the height of the building. For all practical purposes, the requirement of the Building Act, 1855, is the only one applicable to London proper, and accordingly dwellings of such shallow depth that all the rooms in them can have windows in front are to be found which have been erected in quite recent years, and which present the cardinal defects of houses of the back-to-back type.

What the effect upon the health of the occupiers of these dwellings will be remains yet to be ascertained, but, so far as has at present been observed, there is little doubt as to the prejudicial effect. From the mortality tables prepared by Dr. John Tatham, formerly Medical Officer of Health of Salford, and now of Manchester, it has been found that in certain streets and courts consisting of back-to-back houses, unfurnished with through-ventilation, tubercular disease was much more common than in other parts of the same town, and such disease occurred again and again in the same houses. From the same mortality tables it is shown in the Government report already alluded to that the rate of mortality from epidemic diseases, from phthisis, from pulmonary diseases other than phthisis, from other diseases, and from diarrhœa respectively, increased in proportion to the number of back-to-back houses in each of the district areas referred to, comprising the whole of the borough of Salford; and although it is possible that, in the consideration of such statement, a number of other factors ought to be taken into account - such as relative density of population in the districts, social status of the inhabitants, ages at death, &c.—still the fact of the progressive increase in the death-rates from the several diseases mentioned is extremely suggestive of the greater unhealthiness of the dwellings having no through-ventilation. With the information at present available on the subject, therefore, it is not surprising to find that the department of Government concerned with the matter refuses to confirm bye-laws having for their object the regulation of the construction of dwellings unprovided with adequate means of through-ventilation; and, so far as can at present be judged, it seems unfortunate, in the interests of health, that those towns and districts which already possess the power of regulating such a vicious plan of house construction—whether under an old code of bye-laws which would now be considered obsolete or under any local Act of Parliament—should take no steps for securing other regulations more in conformity with modern views of the subject. It is worthy of note in connection with this part of the subject that in the First Report (1885) of the Royal Commission on the Housing of the Working Classes it is recommended that in the rear of every new dwelling house or other building to be controlled by rules ordinarily applicable to dwelling-houses, and whether in old or in new streets, there be provided a proportionate extent of space exclusively belonging to the dwelling-house or building; that this space be free from erections from the ground level upwards; that it extend laterally throughout the entire width of the dwelling-house or building; that for the distance across the space from the building to the boundary of adjoining premises a minimum be prescribed;

and that this minimum increase with the height of the dwelling house or building. The Commissioners, in making these recommendations, recognise the difficulty experienced in providing such open space in the case of towns and districts already laid out, where the value of land has attained considerable magnitude; and they state that the recommendations referred to must be subject to the limitations which would probably be found necessary to prevent undue sacrifice of property in individual cases or in particular areas.

The common lodging-house, regarded from a hygienic point of view, may play an important part in the health conditions of a locality, and for this reason it has been found necessary to provide special means of regulating the conduct of such houses. This is the more necessary seeing that common lodging-houses, according to the ordinary acceptation of the term, are not generally built expressly for the purpose, but are more often, if not always, houses of large size which have ceased to be adapted to the altered circumstances of the locality in which they were erected, and are taken over by some small capitalist who farms them out or manages them by 'deputy,' and thus often turns them to fairly lucrative account. This class of house, however, cannot be regarded with entire satisfaction, firstly, because such houses are largely resorted to by the 'né'er-do-well' class; and secondly, because in those common lodging-houses where accommodation is provided for married couples there is reason to believe that the majority of the men and women, in representing themselves as married, make a false statement. The Public Health Act, 1875, contains some very necessary and useful provisions for the control of common lodging-houses with the view of diminishing as much as possible the objections to them and of rendering them harmless to health. Thus Section 80 of that Act enacts that 'every local authority shall from time to time make bye-laws (1) for fixing and from time to time varying the number of lodgers who may be received into a common lodging-house, and for the separation of the sexes therein; and (2) for promoting cleanliness and ventilation in such houses; and (3) for the giving of notices and the taking precautions in the case of any infectious disease; and (4) generally, for the well ordering of such houses.' If such bye-laws are made and duly enforced it is clear that much will be done to render the common lodging-houses as wholesome and satisfactory as could be expected.

Some uncertainty is supposed to exist as to what houses are to be included in the term 'common lodging-house,' since the Public Health Act, 1875, contains no precise definition of the term. It states, in Section 89, that the expression 'common lodging-house' includes in any case in which only part of a house is used as a common lodging-house the part so used of such house; but this is far from indicating what the term itself generally includes. The question has from time to time formed the subject of consideration by the law officers of the Crown; for as far back as 1853 the General Board of Health, in a circular dated October 17 of that year, communicated to the several local boards the opinion of the law officers of that day as to the meaning of the term 'common lodging-house' in the 14 and 15 Vict. cap. 28. Those officers stated as follows:—

'It may be difficult to give a precise definition of the term "common lodging-house," but looking to the preamble and general provisions of the Act, it appears to us to have reference to that class of lodging-houses in which persons of the poorer class are received for short periods, and though strangers to one another are allowed to inhabit one common room. We are of opinion that it does not include hotels, inns, public-houses, or lodgings let to the upper and middle classes.'

By that part of the above definition which refers to the persons

inhabiting a common lodging-house being 'strangers to one another,' the law officers in a second opinion explained that their 'obvious intention was to distinguish lodgers promiscuously brought together from members of one family or household.'

In reply to the question whether lodging-houses otherwise coming within the definition, but let for a week or longer period, would, from the latter circumstance, be excluded from the operation of the Act, the law officers observed: 'We are of opinion that the period of letting is unimportant in determining whether a lodging-house comes under the Act now in question.'

Since the date of those expressions of opinion one or two judicial decisions have been given as to what constitutes a common lodging-house. One of these is specially deserving attention, as it points to the conclusion that in deciding whether a given house is or is not a common lodging-house within the meaning of the Public Health Act, 1875, regard should in each case be had to the consideration whether the circumstances of its occupation are or are not such that supervision by the local authority will be necessary in order to secure the needed cleanliness, ventilation, good ordering, &c. For the purpose of further facilitating the supervision of common lodging-houses, Secs. 76 to 79 of the Public Health Act, 1875, impose on every sanitary authority the duty of keeping a register of the common lodging-houses in their district, and deal with other matters relating to the registration of them; Sec. 78 provides that a house shall not be registered as a common lodging-house until it has been inspected and approved for the purpose by some officer of the local authority, and to this inspection too much importance can hardly be attached, since it is essential that in all structural details the fitness of the premises should be carefully ascertained before the house is placed on the register. The Local Government Board, in their official memorandum accompanying their model bye-laws with respect to common lodging-houses, suggest the following rules for the guidance of the inspecting officer in his examination of any premises that it may be proposed to place on the register:—

The house should (1) possess the conditions of wholesomeness needed for dwelling-houses in general; and (2) it should further have arrangements fitting it for its special purpose of receiving a given number of lodgers.

(1) The house should be dry in its foundations and have proper drainage, guttering, and spouting, with properly laid and substantial paving to any area or yard abutting on it. Its drains should have their connections properly made, and they should be trapped, where necessary, and adequately ventilated. Except the soil pipe from a properly trapped water-closet, there should be no direct communication of the drains with the interior of the house. All waste pipes from sinks, basins, and cisterns should discharge in the open air over gullies outside the house. The soil pipe should always be efficiently ventilated. The closets or privies and the refuse receptacles of the house should be in proper situations, of proper construction, and adapted to any scavenging arrangements that may be in force in the district. The house should have a water supply of good quality, and if the water be stored in cisterns they should be conveniently placed and of proper construction to prevent any fouling of water. The walls, roof, and floors of the house should be in good repair. Inside walls should not be papered. The rooms and staircases should possess the means of complete ventilation; windows being of adequate size, able to be opened to their full extent, or, if sash windows, both at top and bottom. Any room proposed for registration that has not a chimney should be furnished with a special ventilating opening or shaft, but a room not having a window to the outer air, even if it have special means of ventilation, can seldom be proper for registration.

(2) The numbers for which the house and each sleeping room may be registered will depend partly upon the dimensions of the rooms and their facilities for ventilation and partly upon the amount of accommodation of other kinds. In rooms of ordinary construction to be used for sleeping, where there are the usual means of ventilation by windows and chimneys, about 300 cubic feet will be a proper standard of space to secure to each

person; but in many rooms it will be right to appoint a larger space, and this can only be determined on inspection of the particular room. The house should possess kitchen and dayroom accommodation apart from its bedrooms, and the sufficiency of this will have to be attended to. Rooms that are partially underground may not be improper for dayrooms, but should not be registered for use as bedrooms. The amount of water supply, closet or privy accommodation, and the provision of refuse receptacles should be proportionate to the numbers for which the house is to be registered. If the water is not supplied from works with constant service, a quantity should be secured for daily use on a scale, per registered inmate, of not less than ten gallons a day where there are water-closets, or five gallons a day where there are dry closets. For every twenty registered lodgers a separate closet or privy should be required. The washing accommodation should, wherever practicable, be in a special place and not be in the bedrooms; and the basins for personal washing should be fixed and have water taps and discharge pipes connected with them.

With reference to the amount of cubic space (300 feet) above mentioned as a proper standard to secure to each person in rooms of ordinary construction, there must be frequent instances where a larger amount is necessary —indeed, it is obviously impossible to lay down a hard-and-fast rule, since the requisite quantity of space must depend upon a variety of considerations. In the metropolis the Commissioner of Police has a minimum standard, which is determined in part by the height of the room, and gives about 300 cubic feet to each person in rooms only used for sleeping, and which are unoccupied during the day, inspection being also provided for the purpose of ascertaining that ventilation is efficiently maintained. This amount has been decided upon in view of the difficulties of lodgment in the metropolis, and ought certainly not to be diminished. When a room is occupied both by night and by day at least 400 cubic feet ought to be obtained for each inmate, and this only on the assumption that ample means of ventilation by open fireplace and windows (to open) are also provided. Where children come into consideration, it is common to reckon two children under ten years of age as one person, but this appears to be an unfortunate arrangement, since it is desirable that a child who is growing and developing should have at least as much air space as an adult.

As regards other detail arrangements bearing upon health in connection with common lodging-houses over and above those already referred to, it may be useful here to point out that the model bye-laws of the Local Government Board [1] contain many recommendations on the subject. One of these relates to the arrangement of the sleeping accommodation to be provided for married couples where two or more such couples occupy the same room, and prescribes that each bed shall be effectually screened from any other bed by suitable partitions. These partitions, which are indispensable in the interests of privacy and decency, are usually required to be of wood or other solid material, extending, not up to the ceiling, but to a height of about six feet six inches, so as, while serving effectually to screen the bed, not to interfere unduly with light and ventilation. They should likewise not extend down to the floor, but should stop short some six or eight inches above the floor in order to admit of the free movement of air and to facilitate the cleansing of the whole surface of the apartment. Curtains are sometimes proposed as screens, but their use for the purpose should be avoided, as they are less cleanly than wood or sheet iron, either of which materials can be more conveniently painted and washed. Moreover, as curtains can easily be either wholly or partially withdrawn at the discretion of the lodgers, their use for the purpose of screening and separating the beds loses much value, and likewise renders it impossible to throw the responsibility of maintaining an effectual screen upon the

[1] *Knight's Annotated Model Bye-laws of the Local Government Board*, 2nd & 3rd Editions. London: Knight & Co., 1885 and 1890.

keeper of the house. Wooden partitions as screens round the bed of each married couple have long been required in the metropolis by the Metropolitan Police Commissioners.

Over and above what are known as common lodging-houses, there are two other classes of lodgings that demand special attention, namely, 'cellar dwellings' and 'houses let in lodgings,' both of which are referred to in the Public Health Act, 1875. As regards the former, Secs. 71 to 75 of that Act deal very definitely with the character of such dwellings, but as regards the latter, under Section 90 of the Act, the control of such houses is left far more in the hands of the local sanitary authority, since they may be empowered to make bye-laws for dealing with such houses with the view of enforcing such sanitary requirements as may be necessary in addition to the numerous enactments of the Public Health and other general statutes which may bear upon houses of this description.

As regards cellar dwellings, it is unfortunate from a health point of view that apartments of the kind should be allowed to be occupied as dwellings at all. The 71st section of the Public Health Act, 1875, prohibits the letting or occupation separately as a dwelling of any cellar built or rebuilt after the passing of that Act, and the next section specially prescribes certain requisitions that must be complied with in regard to any cellar dwelling whatsoever. Amongst these requisitions it is laid down that the cellar must in every part be at least seven feet high, three feet of which must be above the surface of the street adjoining; also that a continuous external open area two feet six inches wide be provided along the frontage of the cellar, the floor of which must be six inches below the level of the floor of the cellar; likewise that the cellar must be effectually drained by means of a drain, the uppermost part of which is one foot at least below the level of the floor of the cellar; and further that there be appurtenant to the cellar the use of a water-closet, earth-closet, or privy, and an ashpit, &c., and that the cellar have a fireplace and an external window of at least nine superficial feet, to open in an approved manner, except in the case of an inner or back cellar let or occupied along with a front cellar as part of the same letting or occupation, in which case the external window may be of any dimensions not being less than four superficial feet in area clear of the sash frame. It will scarcely be alleged that these conditions of letting or occupying cellar dwellings, judged merely upon their hygienic merits, are otherwise than extremely moderate, but they are nevertheless frequently infringed. In view of the steps that have been taken in recent years, however, to provide improved dwellings for the poorer classes, it would seem probable that at some not very remote period, if the time has not already arrived, all necessity for permitting the use of cellars as dwellings will cease, and that vast numbers of such dwellings which now scarcely comply with the statutory requisitions, and which can never be made wholesome, will no longer be allowed to be occupied. In the metropolis the requirements as regards cellar dwellings have hitherto been slightly different from those prescribed for the rest of the country under the Public Health Act, 1875; but under the Public Health (London) Act, 1891—Sections 96 to 98—the stringency of the requirements as regards underground rooms (hitherto known as cellar dwellings) has been greatly increased.

As regards houses let in lodgings, the Public Health Act authorises any local sanitary authority, after certain preliminary formalities, to make bye-laws upon the undermentioned matters, and under Section 94 of the Public Health (London) Act, 1891, the sanitary authorities in the metropolis are required to make and enforce such bye-laws as are requisite in regard to those matters.

(1) For fixing and from time to time varying the number of persons who may occupy a house or part of a house which is let in lodgings or occupied by members of more than one family, and for the separation of the sexes in a house so let or occupied:

(2) For the registration of houses so let or occupied:

(3) For the inspection of such houses:

(4) For enforcing drainage and the provision of privy accommodation for such houses, and for promoting cleanliness and ventilation in such houses:

(5) For the cleansing and lime-washing at stated times of the premises, and for the paving of the courts and courtyards thereof:

(6) For the giving of notices and the taking of precautions in case of any infectious disease.

And the Local Government Board, with the view to assist local authorities, have issued a series of model bye-laws bearing to a certain extent upon the several matters referred to. They have suggested the exemption from the operation of the bye-laws of certain houses which, though let in lodgings or occupied by members of more than one family, are of such a character as to render it inexpedient, if not absolutely unnecessary, to bring them within the range of bye-laws having for their primary object the regulation of premises where neglect of sanitary requirements might otherwise ensue, and accordingly a clause is inserted in the model series which provides for the exemption of lodging-houses as to which it may be reasonably inferred that the supervision by the sanitary authority which under other circumstances would be necessary will be sufficiently exercised by the lodgers themselves. The model bye-laws ignore the question of the separation of the sexes as to which the statute authorises the making of bye-laws, but proceed to suggest a few simple rules whereby the number of persons to occupy the several sleeping rooms may be determined with reference to the amount of free air space contained in the rooms. It is suggested that in every room used exclusively as a sleeping apartment a minimum allowance of 300 cubic feet of free air space should be afforded to each person above ten years of age, and 150 cubic feet of space to each child whose age does not exceed ten years. In the case of a room not used exclusively as a sleeping apartment, these quantities of air space are increased to 400 cubic feet and 200 cubic feet respectively. The other suggested clauses in the model series relate to facilities for inspection; to the provision of adequate and suitable water-closet, earth-closet, or privy accommodation, which is fixed at a rate of one such closet to every twelve persons sleeping in the house; and to the general maintenance of the premises, and the several parts thereof, in a proper cleanly and habitable condition, and the windows of the sleeping rooms to be regularly opened for thoroughly airing the rooms; and likewise as to the notification of any case of infectious disease that may be known to have occurred in the house.

The *sixth* class, embracing dwellings of the institution type, has many peculiarities which deserve special attention. Thus the object of each of the several kinds of institution must be carefully considered in regard to the particular hygienic conditions that are applicable to it; for although some of those conditions may be important as regards every type of dwelling, they may be more indispensable in one kind of institution than in another. This will be better appreciated when it is borne in mind that a residential school, in which children of tender age pass nearly the whole of their time, must be so contrived as to comprise the best conditions for establishing the physical health and moral training, as well as the education of the child, during the eight or ten years or more when the constitution is forming, and the body is growing and developing; at a time when everything is requisite that conduces to promote that strength of body and mind which is so important in fostering courage and vigour, and tends to promote the higher qualities—honour,

integrity, and truth. For it seems probable that untruthfulness is, in a great measure, the outcome of fear and timidity, which in its turn is caused by certain low conditions of vitality. The barrack must be adapted to receive the adult man who comes to it in sound health to pass some of the best years of his life, and the conditions must be such as will conduce to the maintenance of his health and strength so long as he remains in the service. Prisons, again, involve a variety of conditions according to the age, duration, and class of sentence, and other circumstances connected with the prisoners. The hospital must be so contrived as to facilitate the cure and expedite the discharge of the patient who is brought to it, and who ordinarily does not remain there more than a short period, rarely exceeding a few weeks. The asylum, in so far as it has to deal with curable cases, must occupy very much the same category as the hospital, but, where it has to deal with those whose age or condition renders the chance of improvement or cure very remote or hopeless, would in many ways come in the same category as the workhouse for aged and infirm, where all that could be expected would be ordinary care and attention, and such arrangement of buildings as would tend to promote the comfort and to maintain the general health conditions of the patients. The workhouse is more or less a combination of residential buildings for the several classes of indoor poor who come under the care of the Poor-law Guardians, for the rearing of children and fitting them to become self-supporting when grown up, for the maintenance of the able-bodied pauper in a healthy state with such employment as can properly be exacted, for the proper care and maintenance of the aged, the infirm, and the harmless imbecile, with reasonable comfort to themselves, and for the care, nursing, and medical attendance of the sick.

In the arrangement of all these buildings vast changes have taken place in recent years, as a result of increased knowledge of hygiene and of the important influence that improved conditions have upon the inmates of the several classes of institution under consideration.

PRISONS

In modern times the earliest substantial efforts at improvement in the arrangement of these institutions are those which were initiated by John Howard in regard to prisons and hospitals. His works upon the state of those institutions, both British and foreign, are standing records of the terrible conditions existing at the latter end of the last century. So far as the prisons were concerned, Howard, who first had his attention drawn to the subject when he was Sheriff of the County of Bedford, in 1773, was struck not only with the shameful administration of the prisons under which those confined, both debtors and felons, were subjected to all kinds of ill-usages and evil practices at the hands of the gaolers and other officers, but also with the general prevalence of what was known as the gaol fever, the gaol distemper, and of small-pox in the prisons; and these diseases carried off by death a far larger number of prisoners who were confined for offences of comparatively slight importance than the actual number of prisoners who suffered execution according to the laws then in force. Writing of the state of the atmosphere in some of the prisons visited, Howard says: 'My reader will judge of its malignity when I assure him that my clothes were, in my first journeys so offensive, that in a postchaise I could not bear the windows drawn up, and was therefore obliged to travel commonly on horseback. The leaves of my memorandum book were often so tainted that I could not use it till after spreading it an hour or two before the fire; and

even my antidote, a vial of vinegar, has, after using it in a few prisons, become intolerably disagreeable.'

This horrible condition of the air of the prisons, together with other gross defects such as insufficient water, bad food, bad drainage, and the like, not only caused many prisoners to die, but a still larger proportion of them were seriously crippled for life. Howard says: 'Certain it is that many of those who survive their long confinement are by it rendered incapable of working. Some of them by scorbutic distempers, others by their toes mortified, or quite rotted from their feet, many instances of which I have seen.'

Some of Howard's recommendations for obviating the defects of the old prisons when a new one was to be erected were far in advance of his time. He says: 'That part of the building which is detached from the (surrounding) walls and contains the men-felons' ward may be square or rectangular,

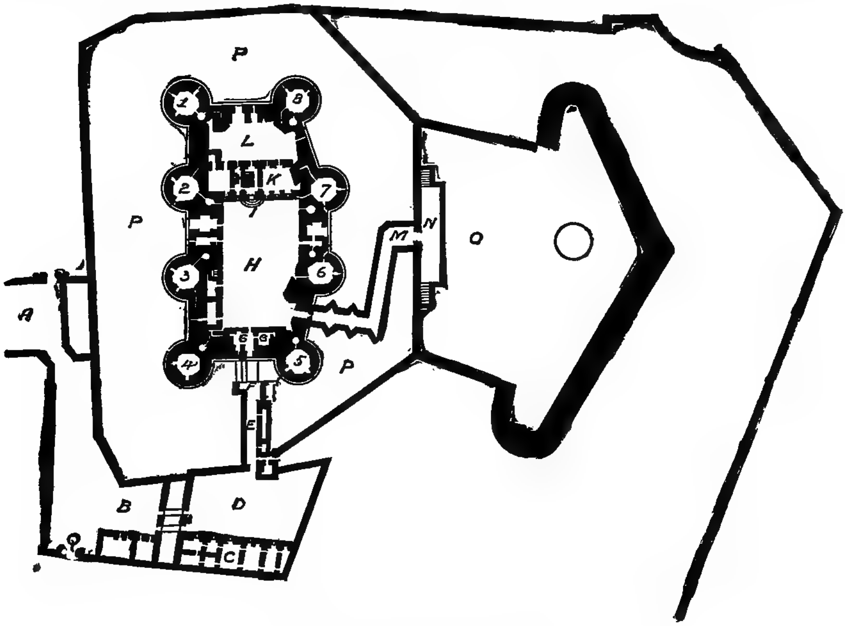


FIG. 125.—The Bastille.

A, Avenue by the street of St. Antoine; B, Entrance and First Drawbridge; C, Hôtel du Gouvernement; D, First Court; E, Avenue leading to the Great Court; F, Gates of the Great Court and Drawbridge; G, Corps de Garde; H, Great Court within the Towers; I, Staircase leading to the Council Chamber; K, Council Chamber; L, Cour du Puits; M, Way to the Garden; N, Steps to the Garden; O, Garden; P, Fosses; Q, Passage to the Arsenal Garden; 1, Tour du Puits; 2, Tour de la Liberté; 3, Tour de la Bertaudière; 4, Tour de la Bazinière; 5, Tour de la Comté; 6, Tour du Trésor; 7, Tour de la Chapelle; 8, Tour du Coin.

raised on arcades that it may be more airy;' and again, 'The infirmary or sick-wards should be . . . raised on arcades.' This plan of raising the wards on arcades or arches 'that they may be more airy' is now not uncommonly adopted in the case of new hospitals in France and Germany, as described below under the head of *Hospitals*. In the days when Howard was engaged in his inspection of prisons the numbers confined were but few compared with the numbers to be found in the prisons of the present day; for formerly large numbers were transported, and many were executed, and the large majority of those detained in the gaols or prisons were mere debtors and persons committed for petty offences. The prisons, moreover, were then very numerous—far more numerous, compared with the population, than at the present day. And yet, notwithstanding the small aggregation of prisoners in those old prisons, serious disease was of most common occurrence.

It will be interesting here to reproduce the plan of the Bastille at Paris (fig. 125), with the description of some portions of it given by Howard, as supplied to him in the form of a pamphlet published in France in 1774, but immediately suppressed :—

'The Castle is a State prison consisting of eight very strong towers, surrounded with a *fosse* about one hundred and twenty feet wide, and a wall sixty feet high. The entrance is at the end of the street of St. Antoine by a drawbridge, and great gates into the court of *l'Hôtel du Gouvernement*; and from thence over another drawbridge, to the *Corps de Garde*, which is separated by a strong barrier constructed with beams plated with iron, from the Great Court. This court is about 120 ft. by 80 ft. In it is a fountain, and six of the towers surround it, which are united by walls of freestone 10 ft. thick up to the top. At the bottom of this court is a large modern *Corps de Logis* which separates it from the Court *du Puits*. This court is 50 ft. by 25 ft. Contiguous to it are the other two towers. On the top of the towers is a platform continued in terraces on which the prisoners are sometimes permitted to walk attended by a guard. On this platform are thirteen cannons mounted, which are discharged on days of rejoicing. In the *Corps de Logis* is the council chamber, and the kitchen, offices, &c.; above these are rooms for prisoners of distinction, and over the council chamber the King's lieutenant resides. In the Court *du Puits* is a large well for the use of the kitchen. The dungeons of the Tower *de la Liberté* extend under the kitchen, &c. Near that tower is a small chapel on the ground floor. In the wall of it are five niches or closets, in which prisoners are put one by one to hear mass, where they can neither see nor be seen. The dungeons at the bottom of the towers exhale the most offensive scents, and are the receptacles of toads, rats, and other kinds of vermin. In the corner of each is a camp bed made of planks laid on iron bars that are fixed to the walls, and the prisoners are allowed some straw to lay on the beds. These dens are dark, having no windows, but openings into the ditch; they have double doors, the inner ones plated with iron with large bolts and locks. Of the five classes of chambers, the most horrid next to the dungeons are those in which are cages of iron. There are three of them: they are formed of beams with strong plates of iron and are each 8 ft. by 6 ft. The *calottes*, or chambers at the top of the towers, are somewhat more tolerable. They are formed of eight arcades of freestone. Here one cannot walk but in the middle of the room. There is hardly sufficient space for a bed from one arcade to another. The windows, being in walls ten feet thick, and having iron gates within and without, admit but little light. In these rooms the heat is excessive in summer and the cold in winter. They have stoves. Almost all the other rooms (of the towers) are octagons about 20 ft. in diameter and from 14 to 15 ft. high. They are very cold and damp.'

If any class of the community need more consideration in regard to the hygiene of his dwelling than another, it assuredly is the inmate of our prisons. He is compelled to occupy whatever accommodation the authorities provide for him, and to endure whatever conditions they may determine. Unlike the pauper, who when destitute may be compelled to resort to the workhouse as a dwelling, he is not permitted to communicate with the outside world; hence it is of the utmost importance that the health conditions of our prisons should be, in all respects, the best. As a type of the modern English prison, and in striking contrast to the old Bastille of Paris, and even to Newgate or the Penitentiary of London, that recently erected for convicts at Wormwood Scrubs, in the west of London, may be referred to. Standing in a very open situation, abutting on a large tract of land that has been made over to the public in perpetuity as a recreation ground, the prison, together with the officers' quarters and various administrative buildings, occupies a site some twenty acres in extent. The old-fashioned plan of arranging the building containing the prisoners' cells in long blocks attached to and radiating from a central inspection block, such as was adopted for, among others, the Model Prison at Pentonville erected fifty years ago, has very properly been abandoned, because the blocks so placed involved the formation of narrow and confined yards between them, in which there was absence of light, stagnation of air, and consequent damp and unwholesome conditions generally.

The principle of arrangement adopted at the Wormwood Scrubs Prison (fig. 126) is that now followed universally in the construction of every large hospital, namely, what is known as the pavilion system. On this principle the whole number of ordinary cells are divided up into four distinct groups, making a total, apart from infirmary accommodation, of 1,378. The four parallel pavilions or cell buildings are each four storeys high, the two middle ones being 228 feet apart and the outer ones 262 feet distant from them. There is thus ample space between them, not merely for free circulation of air and the access of sunlight to both sides of the pavilions—their aspect being east and west—but for exercise yards for the prisoners and for sundry necessary administrative buildings such as kitchen offices, stores, bakehouse, bathhouses with fifty-four baths for the male and twelve for the

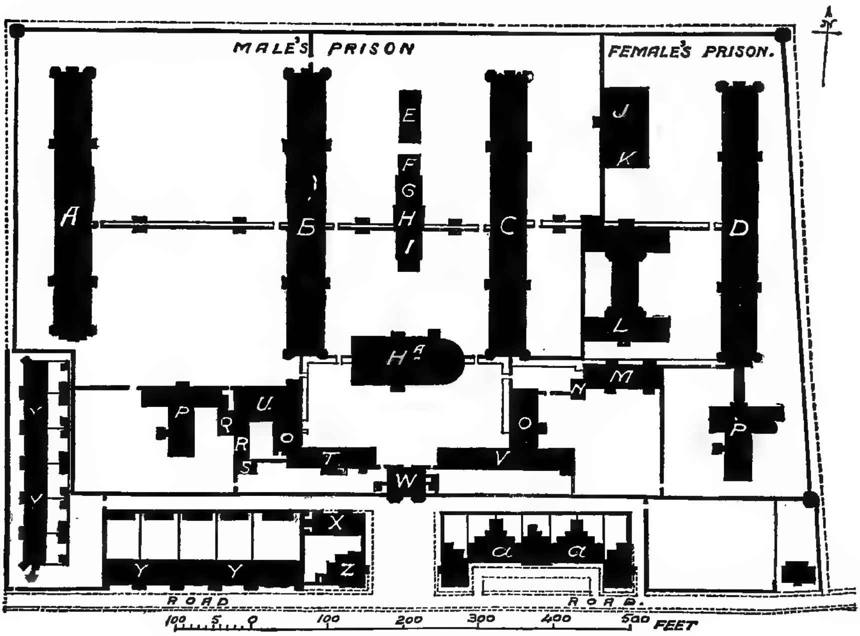


Fig. 126.—Block Plan of Wormwood Scrubs Prison.

A, Cell Building, 327 cells; B, Cell Building, 350 cells; C, Cell Building, 350 cells; D, Cell Building, 351 cells; E, Baths; F, Boiler House; G, Bakery; H, Bread and Flour Store; Ha, Chapel; I, Kitchen; J, Laundry; K, Females' Baths; L, Roman Catholic Chapel; M, Matron; N, Photographer; O O, Offices; P P, Reception and Hospital; Q, Clothes Store; R, Coal Store; S, Dead House; T, Warders' Mess; U, Steward's and Manufacturer's Store; V, Artificers' Shops; W, Entrance Building; X, Officers' Reading Room; Y, Warders' Quarters; Z, Governor's House; A A, Superior Officers' Quarters.

female prisoners, laundry building, &c. The cell buildings are each 48 ft. wide from outside to outside, and each consists of a central hall or corridor 16 ft. wide, extending throughout its entire length, lighted from the ends and roof, with iron galleries about 3 ft. wide at each of the upper floor levels, giving access to a row of cells along each side. The cells are each 13 ft. deep, 7 ft. wide, and 9 ft. high to the highest part of the arched ceiling, and consequently contain fully 800 cubic feet of space. They are each lighted by a window about 3 ft. 6 in. wide by 2 ft. high, glazed with fluted glass, of which about one-seventh is made to open as a hopper, by means of which a small quantity of fresh air can be admitted at the discretion of the prisoner direct from the outside; but as this is fully 7 ft. above the floor level of the cell, the prisoner has no ready access to the opening except by a lever handle within

his reach. The constant ventilation of each cell is effected by a couple of flues in the end walls: one of such flues brings into the cell a supply of fresh air which can be warmed by heating apparatus and pipes beneath the main gallery floor, and the other drawing off the vitiated air into a trunk in the roof leading to a turret in which an upcast current is induced by a fire con-

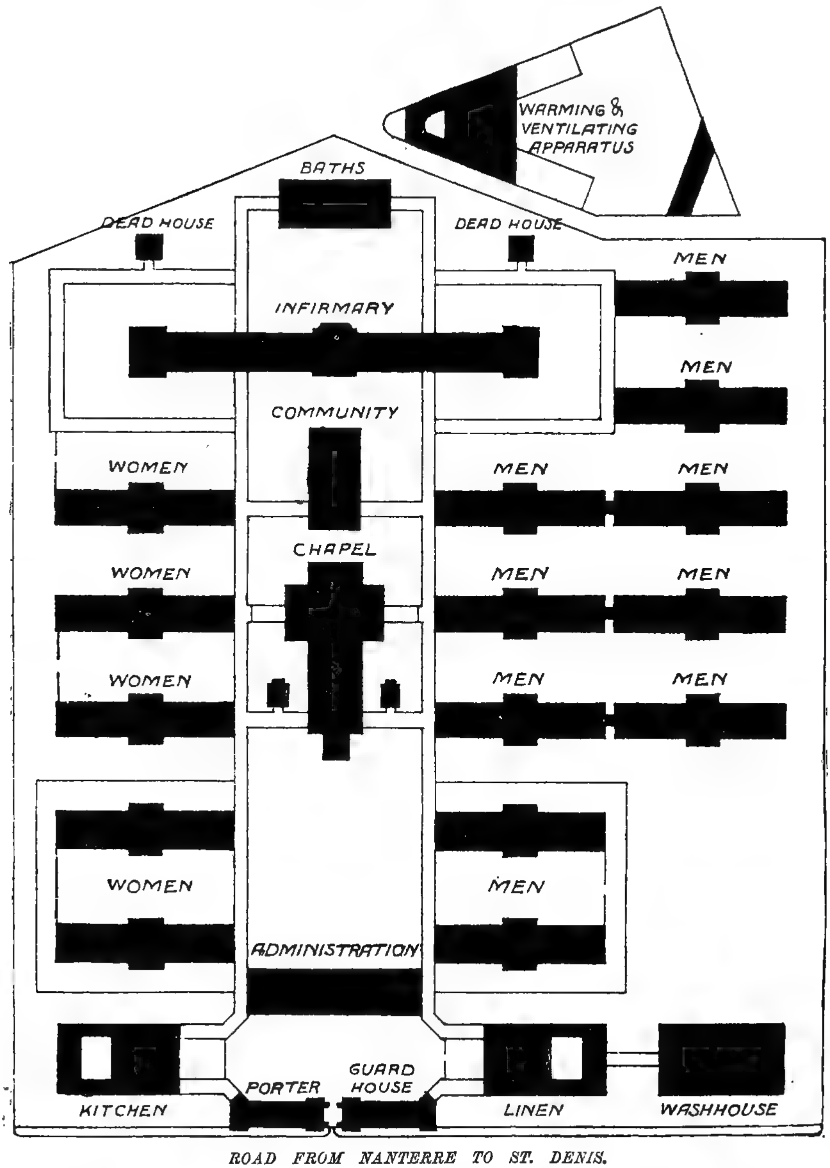


FIG. 127.—Block Plan of Prison at Nanterre.

stantly burning. The outlet for vitiated air is a grating about 18 by 9 in. into a flue in the external wall, about 12 in. above the floor level, and the inlet for fresh air, warmed when necessary, is a similar grating into a flue in the corridor wall about 7 ft. above the floor level. Artificial light is given by a ventilated gas burner in the thickness (18 in.) of the corridor wall with

a ground glass panel next the cell. Each cell is furnished with a couple of shelves in one corner, a fixed table immediately beneath the gaslight, a stool seat, a movable plank-bed which is stood up on end during the day, with a mattress and such bedding as the season may render necessary, a tin urine pot, a can of water and wash-hand bowl; also a tin mug for drinking, a bell-push with indicator in the corridor, and sundry minor articles. The floor is boarded and the walls painted for about 5 ft. of the height, the remainder of the walls and the ceiling being whitewashed. It was formerly the invariable practice to fix in each cell not only a wash-hand basin with waste pipe and cold water supply, but a water-closet apparatus. This, however, has now been entirely dispensed with. A water-closet and a slop-sink closet are provided at four different points on each floor, but these water-closets are rarely used by the prisoners, who are not allowed to leave their cells after being locked up at night, and ordinarily use the latrines out of doors during the day.

In addition to the cell buildings there is, for each sex, a block of reception wards where prisoners on first arrival are seen by the medical officer, and the requisite hospital wards. The latter comprise accommodation for fifty men and twenty-nine women. The men's wards consist of thirty cells, including two padded rooms, and two associated wards of ten beds each; the women's accommodation comprises six cells and two associated wards—ten and five beds respectively—a lying-in ward for four patients and an isolated ward for four. The amount of cubic space allotted to the patients in the hospital cells is 1,400 ft., but in the associated wards, which are not often more than half full, a much larger amount of space is available. The buildings, which have been erected by convict labour, are exceedingly well constructed, and it will be seen that the conditions under which the prisoners are housed leave nothing to find fault with. It might perhaps be contended that 350 is a large number to place together in one pavilion, especially having regard to the fact that many of these undergo confinement in their cells for twenty-three hours out of every twenty-four—being allowed out for one hour of exercise daily—for some nine months after their first admission. But looking to the large amount of air space afforded them, and to the unceasing removal of vitiated air and renewal of fresh air that goes on in every cell, independently of any other cell, as well as to the minute attention that is paid to each prisoner, there is little possibility of his suffering any ill effects from the conditions of residence in prison.

It is not only in England that the hospital plan of arranging prison buildings is being adopted. In France the new prison at Nanterre,[1] near Paris (fig. 127), built to hold 1,000 men and 500 women, is arranged entirely in separate blocks or pavilions. True, the class of inmates is somewhat different from that of our convict prisons, comprising as it does prisoners in the ordinary sense of the term, and mendicants or tramps, together with sick-accommodation for both classes; but these are divided amongst sixteen distinct blocks or pavilions connected together, and with the chapel and administrative offices, by means of covered ways open at the sides.

BARRACKS

These buildings, like prisons, hospitals, and other domiciliary institutions whose fundamental condition involves the aggregation of large numbers of human beings, have in the past formed no exception to the disastrous results that have ensued everywhere from the non-observance or neglect of those

[1] M. Hermant, architect.

hygienic conditions which are essential to the maintenance of the inhabitants in a proper state of health. In all the greater nations of Europe the same difficulties in regard to healthy dwellings for troops have been experienced, and during the present century, when standing armies have been vastly increased in magnitude, these difficulties have become more accentuated. In times of war the results of either ignorance or neglect of the most ordinary rules of hygiene have, over and over again, led to the most terrible loss by sickness and death. This, however, may be to some extent accounted for by the exigencies of warfare, the arrangements being perhaps only temporary; but that such results should have occurred in times of peace, when every arrangement is made with the utmost deliberation, and the buildings are provided for the permanent dwelling of the men, is a far more serious matter. The lessons gained at so much cost, both of life and money, in various campaigns in Europe and America, during the third quarter of the present century, have tended to produce a universal reformation in barrack arrangement, which, however, it has unfortunately not been found practicable to fully carry out, and consequently, where old barracks have been retained, even though costly alterations, as palliatives, have often been effected in them, evil results due to the same causes have still occurred. Not only has this been the case in the British Possessions, but especially in France, Germany, Austria, and Italy, with their large armies, similar difficulties have been experienced.

The old French plan, advocated by Vauban in the middle of the last century, of forming a barrack for a large number of men—a whole regiment—in one huge building arranged round the four sides of a quadrangle, judged by our present knowledge, was bad enough, but it was rendered far worse later on, when owing to the general increased strength of the permanent armies, these already huge buildings were enlarged by additional storeys or otherwise, until they would hold 2,000 or even 3,000 men. Notwithstanding extensive systems of artificial ventilation that were introduced, notably in the Prussian and German barracks which had been thus enlarged, it was found that the rate of sickness and mortality invariably increased. Mons. Tollet, an eminent French civil engineer, who has paid much attention to the construction of barracks and hospitals, since he noticed the deplorable condition of them while he served in the *Corps du Génie* during the Franco-German war, writes in 1882 that during ten years France lost 40,000 men in the barracks, while some 60,000 men, who had entered the service in good health, were discharged on account of illness or infirmity. Typhoid fever alone is said to have killed 12,000 men. This disease and the destructive lung disease commonly known as phthisis appear to have been the chief causes of this terrible loss, and the late Dr. Parkes pointed out how, in our own barracks, both at home and abroad, as well as in those of many other nations, these two diseases are intimately connected with defective dwellings, the one pointing to bad drainage arrangements, and the other to the constant breathing of an atmosphere vitiated by respiration.

In our own country, previous to the end of last century, barracks were rarely constructed, owing, among other reasons, to the strong antipathy of the people to support anything in the shape of a standing army. There were a few garrisons for fortified towns and there was the bodyguard for the protection of the person of the sovereign, but there was no considerable standing army. The first barrack proper that was constructed in London, apart from that for the garrison at the Tower, was that built for the Horse and Foot Guards at the Palace at Whitehall on a portion of the site of the present Horse Guards. In 1716, a project, of

which the plans are still preserved, was put forward by an architect named Nicholas du Bois, for an immense barrack for some 7,000 men to be erected in Hyde Park. It comprised a range of buildings four storeys high, including garrets, 1,335 ft. long, by 369 ft. deep, and was to stand near the south-east corner of the Park, parallel with what is now Park Lane. It enclosed three quadrangles, the middle one being 597 ft. long by 281 ft. wide, and each of the other two 281 ft. square; and the interior was divided into a multitude of small rooms of equal size (about 20 ft. × 20 ft.), placed back to back, and intended for twelve men in each. The plans include a small infirmary placed on the south boundary against some adjacent houses and with only a northern aspect, also a chapel with (significantly) a graveyard on each side. This barrack, which, however, was never erected, affords a fair sample of the kind of building then considered suitable for the purpose.

By 1740 a few barracks of very makeshift sort had been erected in different localities, and in 1786 a military department was formed, and a number of barracks were hastily begun, but were speedily suspended. Later on—1793–97—barracks were built in all the more important towns, but these, as might be expected, were of a very defective type. It was not, however, until after the Crimean war that the whole subject of barrack accommodation was carefully studied. It was then (1857) found that while the death-rate of the civil male population, between the ages of 20 and 40 years, was 9·8 per 1,000, the mortality among the troops was 17·11, or nearly double. The barracks of the whole kingdom were examined and reported upon by a special commission and were found to be defective in many matters of primary importance, and this inquiry led to a number of recommendations, which were followed by regulations prescribing the superficial and cubical space to be provided for each man; the abolition of the offensive urine tub, that had invariably formed one of the articles of furniture in every old barrack-room; the provision of separate quarters for the married men; the provision of baths, washing arrangements, workshops, reading and other recreation and education rooms, and the regulating of warming and ventilation, water supply, drainage, and sanitary details generally. The beneficial results of this improved system of barrack construction speedily showed themselves in the greatly diminished mortality and sickness among the men, for whereas in 1857 the mortality of the troops had been nearly twice as great as that of the civil male population of the same age, in 1876 the mortality of the troops had been reduced to nearly 2 per 1,000 less than that of the corresponding civil male population; and the amount of hospital accommodation necessary for troops has been diminished from 10 per cent. to 6 per cent.

Barrack construction for British troops is necessarily very diversified in character, since our soldiers have to be quartered in every climate under the sun, and what is most suitable for our home garrisons would be wholly unsuited either to our tropical possessions in the Mediterranean, West Indies, and India, or to the climate of our Canadian Dominion. In all these cases the amount of space allotted to each man, and the numerous other arrangements for maintaining his health and protecting him from the effect of climate, have to be specially considered according to the particular local circumstances.

For the temperate climate of the home countries the War Department have issued a series of statements of the various requirements for barracks for the several branches of the service, and in accordance with these a large number of barrack establishments have been erected in different parts of the kingdom where military centres have been formed under the reorganised

arrangement of the home portion of our army.[1] These modern barracks, which are required to stand on a site of some ten acres in extent, exclusive of training and encamping ground for militia regiments, are for the most part planned upon the separate block system, and comprise a number of detached buildings so placed relatively one to another as to admit of ample circulation of air about them, and free access of light and sunshine. The infantry barrack for a battalion of 850 rank and file of eight companies, with its proper proportion of officers, non-commissioned officers, and married men, bringing the total up to very nearly 1,000 of all ranks, with the necessary stabling for the field officers' horses, constitutes a formidable establishment involving much care in the arrangement of the quarters in order to secure those hygienic conditions necessary for maintaining the men, women, and children in proper health. A cavalry regiment, consisting of some 30 officers and nearly 650 non-commissioned officers and men, a few being married, and their horses, or a battery of Royal Horse or Field Artillery, comprising some six officers and 150 non-commissioned officers and men, with the necessary troop-horses and gun-horses, is likewise an assemblage that calls for exceptional consideration in regard to the hygienic arrangement of their dwellings.

In each of these instances provision has to be made for the social and recreative entertainment and physical exercise, both of the officers and men, in order to promote the maintenance both of mental and bodily health, and arrangements have generally to be made for dealing with cases of sickness or casualty, as well as for maintenance of discipline and for certain punishments. For these purposes, besides the quarters for the officers and the men, married and single, the complete barrack must comprise an officers' mess, billiard room, &c., and rooms for mess-man and servants, recreation room, sergeants' mess, canteen, cook houses, guard house with cells and prisoners' room, &c., library and reading-room, coffee room, gymnasium, skittle alley, fives court, chapel-school, adults' school, children's school, and a number of other offices and outbuildings. So far as the residential part of these buildings is concerned, much criticism has been offered upon the absence of day rooms and rooms in which the men should take their meals, the 'barrack rooms' alone being required. According to the statement already referred to, in a barrack for a regiment of infantry, thirty such rooms are prescribed, each room being 77 ft. long by 21 ft. wide and about 10 ft. 6 in. high. These 'barrack rooms' afford accommodation for from 20 to 32 men, giving about 600 cubic feet, and from 57 to 60 superficial feet per man. Windows are required to be placed in the opposite side walls of these rooms, about five feet super of window space (measured within the inside bead of frame) being allowed to each man. The beds are placed in pairs about eighteen inches apart between the windows, with their heads six inches from the wall. It is certainly undesirable that meals should have to be taken in the same room as is used for dormitory purposes, and it would be unfortunate if the men were obliged to pass many hours of the day in these rooms; but seeing that the men are necessarily out of doors a good deal, and that other rooms and places are provided in which they can read and amuse themselves in a variety of ways both physically and mentally, there is little left for adverse criticism on this head. The general arrangement is, in fact, an adaptation of the plan now generally advocated for hospital buildings. As will be seen from the annexed diagram (fig. 128), the barrack room must have ample means of thorough ventilation; a urinal, for night use only, is provided in a cross-ventilated projection from the barrack room; the ablution room is perhaps rather small considering the number of men to use it, but it is well fitted up

[1] The Military Forces Localisation Act, 1872.

and includes a foot pan, which is said to be much appreciated by the men. These blocks are restricted to two storeys in height, and, when placed longitudinally in parallel rows, a clear distance equal to at least twice the height of the blocks, from the ground level to the eaves, has to be provided between them. The married men's quarters are arranged in a somewhat similar block, but divided up into thirty-one independent sets of rooms, each set consisting of a living-room, bedroom, and small scullery, with a central staircase giving access to an open gallery on the upper floor, by which the several sets of apartments in that storey are approached. The block also includes an infants' schoolroom and a class room.

The views which in this country have prompted the complete rearrangement in our barrack buildings, and the results that have attended these changes, have been duly noted in certain other countries of Europe. But it is chiefly in France where improvements on a large scale are being effected. At the International Congress on Hygiene, held at Paris in 1878, M. Tollet, the civil engineer already referred to, read a paper on 'Les Logements collectifs, Hôpitaux, Casernes, &c.,' in which, after referring to the reform that had taken place and was still being carried out

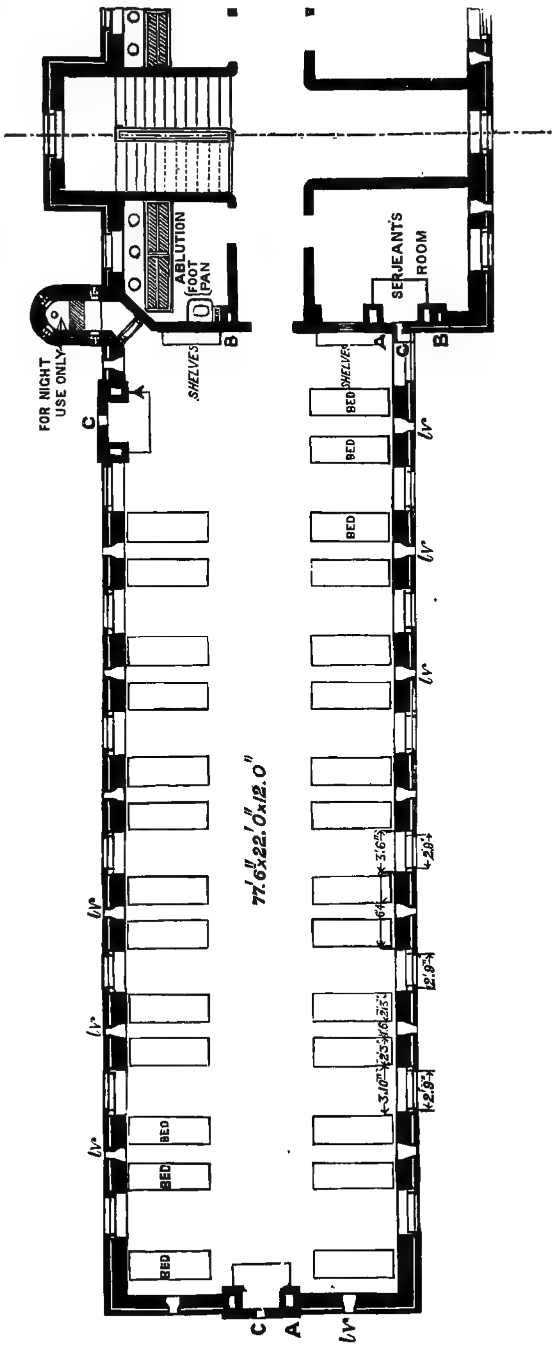


Fig. 128.[1]

[1] From the *Transactions of the Royal Institute of British Architects*, Session 1880–81, by permission of the Council.

in the English barracks, and to the large diminution of mortality and sickness that had resulted therefrom, he urged with much force the extreme necessity for similar reforms in France. In the following year M. Emile Trélat, a well-known architect, who has done much for hygiene in France, presented two important reports to the Société de Médecine Publique, in one of which, after referring in eulogistic terms to the steps taken in England under the direction of Lord Panmure and Lord Herbert to improve the conditions of the soldier, he laid down certain principles under which the French barracks stood condemned. He pointed out that the barracks erected according to the plan adopted previous to 1874 contained conditions which threatened the wholesomeness of the buildings, that they held far too many soldiers under one roof; that they were unfortunately composed of many storeys; that they contained within the material of the walls themselves dangerous and offensive matter which had been absorbed during long periods of occupation without

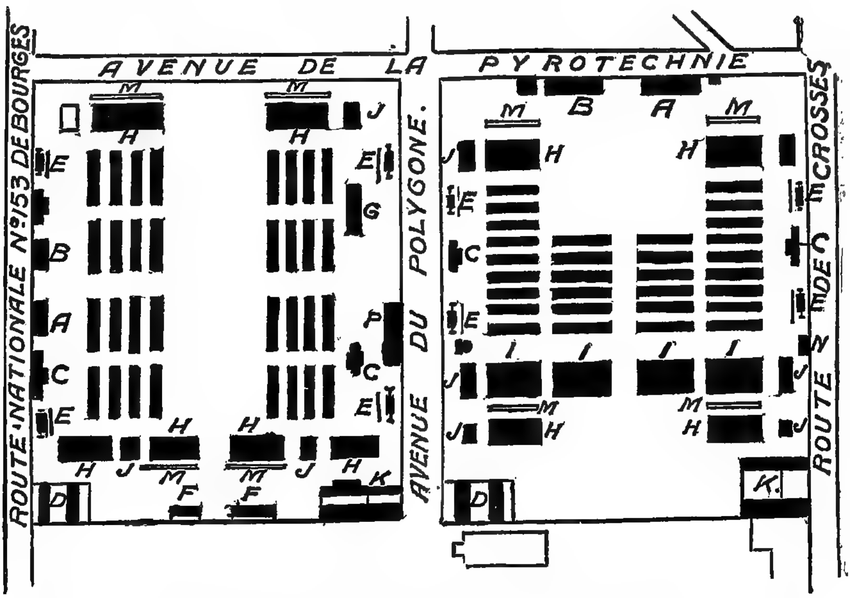


FIG. 129.—Block Plan of Artillery Barracks at Bourges.

A B, Entrance Pavilions; C Kitchens: D, Infirmary for Men; E, Latrines; F, Punishment Cells; G, Canteen; H, Stables (Tollet System); I, Stables (Dock System); K, Veterinary Infirmary; L, Drill Sheds; M, Watering place for Horses; N, Lavatory; P, Reserve Clothing Store.

efficient ventilation; and that the capacity of the buildings afforded insufficient cubic space per soldier. He continued that it was most urgent that this state of things should be altered, and advocated the system of M. Tollet. That system was adopted at the new barracks which were built shortly afterwards at Bourges (fig. 129); it consists of a number of detached blocks, of limited size and only one storey high, which afford a large amount of cubic space to each man, while the aëration and ventilation of the interior is such as to prevent the absorption into the walls of the offensive matters emanating from continued habitation.

SCHOOLS

The hygiene of schools appears to have received a smaller share of attention from the specialist than the subject deserves. There are many valuable reports and essays bearing indirectly upon the subject and upon particular

aspects of it, but it can hardly be said to have been dealt with in as wide and comprehensive a manner as is required. Hitherto, so far as the Education Department of the Privy Council is concerned, no attempt appears to have been made to treat of the hygiene of schools beyond the mere schoolroom and its accessories, because that department is but little concerned with matters other than educational. It would seem that health questions are at best of secondary importance there, and, if dealt with at all, they are not subjected to that searching investigation by trained and skilled specialists that is requisite to place them beyond doubt.

The Association of Medical Officers of Schools has undoubtedly done good service in dealing with certain questions of school hygiene; but this again would seem to have reference more to school management and administration and to the means of excluding infectious disease than to the maintenance of the general health of the residents; and even here the subjects are not dealt with in their application to those numerous residential schools to which children of the poorer classes are sent so much as to the great public schools, which, as a rule, receive children of superior constitution. In fact, many very important questions bearing upon the arrangement and construction of residential schools remain unsettled and even unformulated.

There is certainly a general consensus of opinion that the amount of floor-space and cubic-space commonly prescribed for each child in schoolrooms is very scanty, notably in those schools which come under the inspection of Government, or in respect of which there is a grant of money calculated upon the number of children and the degree of education attained, but no serious effort has hitherto been made to get that amount of space increased. Meanwhile, whenever any communicable disease is prevalent in a locality—such as measles, scarlatina, diphtheria, &c.—the village school or the national school is often found to be one of the chief means of disseminating the disease. Although this is frequently the case, it is not invariably so. There are instances where, in the same locality, it is alleged that one school has been specially affected, while two or three other schools, in quite near proximity, have been either very slightly affected or have even escaped altogether. If this be so, there would seem to be ground for supposing that a cause might be found for the diffusion of the disease in the one school and the whole or partial immunity of the disease in the other schools. Can this immunity be owing to any difference in the condition of the children themselves, or to better ventilation; to a greater amount of cubic space per child, or to a smaller number of children being ordinarily aggregated together, or to any difference in the duration of school hours, or to some combination of better conditions under which the children in the one or more schools are rendered less susceptible, or the power of attack possessed by the disease is diminished or removed? It at least seems to deserve careful investigation and skilful inquiry. But this question is referred to as affecting schools intended for educational purposes alone. If so important a matter applies to those schools, how much more important is this question, and indeed a number of other questions that might be suggested, in their bearing upon the residential school, in which institution the children not only receive education, but remain, night and day, for several years; in which they sleep, feed, play and receive such attention as is available in case of sickness! Such schools exist all over the country, whether as charitable institutions for orphans and afflicted children, or Poor-law institutions for the children of destitute persons and for deserted children, as well as a number of higher class institutions of kindred purpose. Very little, comparatively, has been

hitherto done in the way of literature upon this particular branch of the subject. Schools, more especially residential schools, ought to be the fittest place in every respect for the youth, of whatever age and of either sex. Charitable institutions and other residential schools intended for the entire care and education of the young are erected from time to time, but no common plan or system appears to have been hitherto advocated. In the case of hospitals certain general principles of arrangement are now universally recognised. Not so, however, in the case of schools of the kind referred to. They are generally arranged in any fashion that may commend itself to the governing body for the time being, and accordingly every conceivable variety of arrangement is to be met with—good, bad, and indifferent having been alike adopted down to the present moment.

There are, for example, numbers of large residential schools and colleges for upper, middle, and lower classes throughout the country, some affording accommodation for several hundred pupils, in which the chief building, containing the whole of the administrative, domestic, and educational departments, as well as the dormitories, is arranged two or three storeys high in the form either of the letter E or the letter H, and in some instances it is arranged round the four sides of a quadrangle, or perhaps two sides of the quadrangle are extended so as to form a second quadrangle. Another example is where the school, though still one large block with projecting wings, is subdivided internally into groups of some fifty children or more. This is specially the case at the London Orphan Asylum at Watford. A further variety of residential school is to be found in the Stockwell Orphanage, London, where the children occupy a row of houses (about thirty children in each) specially erected for the institution. The Home for Little Boys at Farningham in Kent, and the Princess Mary's Village Home at Addlestone, Surrey, are examples of the cottage home system, the houses of the former containing about thirty, and of the latter ten and fifteen children each; and the Philanthropic Society's Farm School (a reformatory school) at Redhill, Surrey, is another variety of the same system, but here the several cottages contain an average of some sixty boys. A somewhat similar arrangement is in operation at many of the great public schools for boys, where the masters' houses are scattered about the town, and each contains sleeping and day accommodation for some twenty or more boarders. The institutions that have been erected under the auspices of the Poor-law Authorities might fairly be expected to afford the best examples of what such schools ought, hygienically, to be, since they have been provided under a certain amount of continuous watching and supervision of the whole subject, and with the experience gained during many years of systematic inspection; but even here no very definite conclusions appear to have been arrived at, though certain comparatively recent experiences have led to the condemnation of the principle of erecting a large residential school in one huge building. The Local Government Board have certainly framed some useful rules for the guidance of those proposing to provide schools for pauper children, but much latitude has been left—and wisely so at present—as to the precise system to be adopted in the arrangement of the building, great hesitation being shown in advocating any particular plan.

The necessity for ensuring the best hygienic conditions in buildings for children, of whatever social class, is more than ever important now that the strain upon the child under the modern system of education is so much greater than formerly, and consequently everything that may conduce to counteract this strain and pressure of education is indispensable, whether it concern the internal arrangements—the dormitories, the school and class-

rooms, the play and other day rooms and industrial work-rooms—or the external arrangements, such as the playgrounds, playsheds, gymnasia, cricket fields, and other outdoor provisions for recreative and physical training and exercise. As regards these latter, it has to be borne in mind that in proportion as the children belong to the lower grades of society, so do they require greater inducements to take physical exercise—indeed, it has truly been said by Mr. Nettleship, F.R.C.S., that children, especially those of the poorer classes, will no more take spontaneously to recreative exercises and games than they will spontaneously learn to read or write. Both Mr. Nettleship and Dr. F. J. Mouat before him have pointed out that the children of the lower classes must be *taught* to play games out of doors, to swim, and otherwise to take active exercise. While in the high class public schools the boys have a sort of hereditary liking for games involving considerable physical exertion, and which, by means of permanent clubs, are perpetually kept up, the children in the schools of the poorer classes are more apathetic, and unless the teaching staff systematically teach the children how to play and enter into the games with them, there will almost certainly be a strong tendency on the part of the children to idle about the most objectionable parts of the yards and places provided for them to play in, the result of which is likely to be the reverse of beneficial, and to induce a prejudicial habit of loafing, and this notwithstanding that every requisite for games is provided. A further point that is often insufficiently appreciated in the laying out of schools of the class referred to is the secondary consideration that is given to the extent and suitability of the recreation grounds, since it not uncommonly happens that the larger portion and better situated land is set apart for purposes of profit in the shape of potato and cabbage gardens, farming, &c., instead of being regarded as primarily requisite for recreative outdoor exercise by the children. And this tendency to exaggerate the importance of farming, to the sacrifice of the physical exercise of the children, is fostered by the circumstances that the superintendent of the institution is often able to show a considerable profit upon his farming account for the year, and thus he becomes converted from a school superintendent, whose first care should be for the children committed to his charge, into a mere farm bailiff.

As regards the hygienic conditions that have to be observed in the arrangement of the residential school building itself in which children have not only to be educated, but maintained and cared for during every condition of health and sickness that may occur from early infancy until they are able to go out into the world to earn their own living, it is not too much to say that the principles usually applicable to hospitals are equally applicable to such schools. The child may fairly be regarded as a most sensitive instrument, which indicates very promptly, and with much precision, any variation of the health conditions under which he is placed.

The only class of such institution that has hitherto been systematically under observation would seem to be the Poor-law schools throughout the kingdom. In these schools—chiefly in the larger ones—a variety of complaints have prevailed amongst the children which have formed the subject of much inquiry. Ophthalmia, itch, and diseases of the skin and scalp have hung about some of these schools for long periods, often with results now known to be life-long in their prejudicial influences. The mortality rate of these schools is often quoted by those interested in regarding them favourably as indicating their good condition, but this is a very indifferent test. A far better one is to be found in the rate of *sickness*, and this in some instances has been ascertained to be as high as 25 per cent. of the inmates. Dr. F. J. Mouat, who had large experience of the Poor-law schools, has pointed to a variety

of affections that may be fostered in some of these schools.[1] He says: 'The stunted, impaired general health, and feeble bodily powers of too many of such children are not removed or corrected by massing them in large buildings or groups;' and he suggests that 'there is a large and possibly increasing factor of imbecility, idiocy, and nervous disorders generally, and some of the more immediate results of scrofula at the critical periods of life, which may be due to the insanitary conditions' inherent to the aggregation of large numbers of children in such huge buildings.

But the complaint that has served most readily to indicate the defects in hygienic arrangement in these schools has undoubtedly been ophthalmia. Instances could be cited in which it had prevailed incessantly to an unfortunately large extent for many years, notwithstanding the most indefatigable, skilful, and indeed enthusiastic attention of the school authorities and medical officers in charge. Mr. E. Nettleship has asserted that this disease 'is the touchstone of the general healthiness of an institution.' He says, too: 'Where many persons are herded together their eyelids show sooner and more certainly than any other part if the conditions of vigorous health are not complied with.' The disease was formerly common in the army and navy, but with improved hygienic conditions in the barracks and ships it has been practically abolished. Travellers in the East have always been struck with the remarkable number of blind persons, and poor people suffering with ophthalmia, who are met with in all Oriental towns and villages where intense crowding and other insanitary conditions permanently exist. The intensity of the disease varies much according to the surrounding conditions, but in the large Poor-law schools, both provincial and metropolitan, it has certainly given much trouble, and accordingly it seems probable that advantage would result from a careful and systematic study of the effects resulting from the various arrangements of building that have been tried in the case of these schools. In those domiciliary schools where the children are usually of a higher class, the tendency to disease consequent upon indifferent hygienic arrangements may and doubtless does exist,[2] though in a slighter degree by reason of a variety of circumstances such as the superior condition under which most of the children are reared before being sent to school, and the fact of the children in these schools having the advantage of periodical change during the three usual annual vacations, when they go home or to stay with friends. These circumstances would probably tend to arrest or divert some of the evil results that might otherwise ensue were they to have the same continuous and uninterrupted residence in school which the children in the Poor-law schools have necessarily to endure. And it seems probable that the pallor and lassitude often noticed in children of this higher class at the end of a term, and which is commonly attributed to hard work in school, is in reality more or less due to the conditions of aggregation and defective ventilation referred to.

Some allowance must certainly be made for the low standard—mental, moral, and physical—of the majority of the children of Poor-law schools when comparing them with the higher-class children just referred to, and even with those of the labourer or artizan who has struggled successfully with the trials and inconveniences of very limited means; but this would scarcely diminish the usefulness of the investigation above suggested. The mere history of Poor-law schools is in itself instructive. In the early workhouses

[1] *Paper on the Training and Education of the Children of the Poor.* Read before the Statistical Society, April 20, 1880. London: Stanford & Co.

[2] Mr. Nettleship, in his *Report on Ophthalmia in the Metropolitan Pauper Schools* 1875, states that he has found the disease prevalent in certain other han Poor-law schools.

of 1835–40 the children were but imperfectly separated from the adult indoor paupers. Later on, as increased accommodation for the indoor poor became necessary, the children were moved into a detached building still situated on the workhouse premises; and gradually it was found desirable to remove the children altogether away from the workhouse wherever their number was such as to make such a plan feasible. By degrees the children from the large workhouses of the metropolis and some of the provincial towns were provided for in separate institutions in the suburbs—an arrangement which was undoubtedly a vast improvement in many ways. But with the aggregation of such large numbers of children—for in many instances several Poor-law unions combined, under statutory power, to provide for the children belonging to those unions in one large institution—fresh difficulties arose, and amongst these was that of maintaining the children in good health.

Notwithstanding the removal of the children from the more densely populated areas in the towns and metropolis where the workhouses were situated to newly erected buildings designed specially for the purpose, and situated on large sites in the comparatively open country, it has become only too evident that this alone was quite inadequate to keep them in a proper condition of health. For many years past the children so circumstanced have suffered repeatedly, or more or less continuously, from various complaints, but the disease that has prevailed and given more trouble than any other has been ophthalmia in various stages of severity. And when once any complaint of that character gets into an institution of the kind containing under its one roof a vast number of children, it has been found most difficult to get rid of it. The best advice available has been obtained, specialists have been called in as consultants, and large sums of money have been expended in the hope that the complaint would be eradicated and the health of the children re-established, but with very indifferent success.

These large institutions with vast aggregations of children have come to be regarded more or less as failures; and, as in the case of hospitals and other institutions, subdivision of building, on the principle of separate pavilions, is pointed to as one of the chief means of arresting the evils complained of, and a most important means of preventing the recurrence of them.[1] Accordingly, in recent years residential schools for considerable numbers of children have been arranged either in distinct blocks or pavilions, each to contain a very limited number of children, or upon what is now known as the cottage-home system. On both of these systems many residential schools have been erected both under the Poor-laws and also for charitable purposes; thus as an example of the former of these systems the London Orphan Asylum at Watford may be referred to—an excellent charitable institution consisting of a number of independent blocks, attached or semi-detached, but without any internal communication one with another, each containing dormitory and day accommodation for about fifty children, with apartments for an officer in charge, grouped about the necessary administrative and educational buildings. The cottage-home system is more modest in character and admits of greater diversity in design, comprising as it does a sort of complete village, the cottages being sometimes of different sizes and design, and either detached, semi-detached, or in rows. Each cottage is usually in charge of a foster mother or foster parents, the 'family' comprising a number

[1] So much is this subdivision of building recognised as necessary for purposes of health that in one large Poor-law school at Hanwell the main building, which is upwards of 600 ft. long, has recently been divided into five distinct blocks by having gaps cut through it at four points in its frontage.

of children varying from about ten to as many as thirty, sometimes exclusively of one sex and occasionally of both sexes, according to the ages and characters of the children. The 'village' usually includes a school building, industrial workshops, and such other buildings in the way of infirmary, probation wards, superintendent's house, &c., as the circumstances necessitate; but these are commonly of very modest pretensions, as one of the cottages in a slightly modified form can be made to serve each or any of these purposes, and the need for infirmary accommodation in these villages is never very great, while in each 'home' a small spare bedroom is generally provided in which a case of slight indisposition may be temporarily separated from the other children so as to be more directly under the observation of the foster mother.

Schools on the family system, with agricultural labour as the chief industrial training, have been in operation on the Continent much longer than here, for Pestalozzi introduced into Switzerland farm schools on this plan shortly after the middle of last century,[1] and the reformatory school at Mettray, similarly conducted, has been in existence for nearly fifty years; but even in the United Kingdom the system has been in operation, both under the Poor-laws and at charitable institutions, a length of time sufficient to warrant an opinion being formed regarding it, and in this particular it seems to leave little to be desired, especially as regards the health of the children.[2]

It would seem that until within recent years one of the chief hygienic defects in the arrangement of residential schools consisted in the undue aggregation of the children. They occupied a huge building three or more storeys high, large numbers were placed together in each dormitory, the dormitories were situated along both sides of a corridor which had well-holes in its floor for the passage of light from the roof of the uppermost one down to the lowest one, and the school and day rooms in the lowest storey were similarly placed and were occupied continuously by large numbers of children; and thus the whole building was arranged so as to contain one atmosphere uniformly vitiated by the exhalations of a vast number of individuals as well as by other common means of contamination. These arrangements undoubtedly tend to lower the standard of health and to foster any tendency to disease that may already exist in the individual children, while they cannot fail to promote the intercommunication of any complaint that may be introduced among the children. The remedy for this defective condition is to be found mainly in the converse of the arrangement. The children, instead of being aggregated, must be segregated everywhere. The buildings must be subdivided into detached separate blocks; the dormitories must be of more moderate size, and, as well as the school and day rooms, must have as good means of ventilation as is usually required in the case of hospital wards. The schoolrooms must afford increased area per child, and inasmuch as it is said to be necessary to have considerable numbers together for purposes of teaching, the occupation of the schoolroom must be limited to comparatively short periods between complete evacuation and exposure to fresh air by open windows; and arrangements should be made for conducting a fair amount of

[1] *Statistics of the Farm School System on the Continent.* By Joseph Fletcher. London: Stanford & Co., 1878.

[2] For a further account of the system see *Report of Dr. F. J. Mouat and Captain J. D. Bowly, R.E., on The Home or Cottage System of Training and Educating the Children of the Poor.* London: Printed for the House of Commons, 1878. Since the date of that report a number of schools on this system have been built in various Poor-law unions of England and Wales, notably, for Birmingham, King's Norton, Wolverhampton, Leicester, West Derby, Shoreditch, Bethnal Green, Kensington and Chelsea, &c.

school teaching in the open air, under cover if necessary, whenever the weather will permit. For this purpose large trees are excellently adapted in hot summer weather, and whenever such trees exist about a school or on the site of an intended school every effort should be used to retain them.

The rules of the Education Department as to the planning and fitting up of schools state generally that 'sanitary laws are here as vital as in a hospital,' and, under the head of 'Windows,' the ordinary rules respecting hospitals should here be remembered. Hence it may be inferred that through-ventilation by means of opposite external windows is deemed requisite in schoolrooms erected under the auspices of that department, as it is in the case of schoolrooms for pauper children erected under the authority of the Local Government Board; but the important question of the number to be assembled together in any schoolroom does not appear to have been dealt with, the first point considered in planning a school being how 'to seat the children in the best manner for being taught,' and this tendency to aggregation of unlimited numbers has been noticed by Mr. Nettleship when, in reference to ophthalmia in a large school, he observed that hardly any attempt seemed to have been made to treat the children otherwise than collectively. As, however, it is admitted that the observance of sanitary laws is as important in a school as in a hospital, it is certain that children cannot be aggregated in a schoolroom with impunity any more than patients can be safely aggregated in a sick-ward. The length of time the children are kept in school being only a few hours at a stretch may cause the prejudicial effects to be less readily observed than in the case of the patients in continuous occupation of a sick-ward, but that evil results ensue from massing large numbers together in schoolrooms will be generally admitted. These evil results will be increased or diminished in intensity, but not wholly removed, in proportion to various circumstances—e.g. the general health condition of the children, the amount of floor area and cubic space allotted to each child in the room, and the efficiency of the ventilation and warming of the room; but the question of the maximum number that may properly be collected together in the schoolroom—and in this must be included those classrooms which open out of the schoolroom or are in direct aërial communication with it—must ere long be more generally considered in order to promote the subdivision of the children.

The amount of space for each child in a schoolroom is a detail which in recent years has received more attention than formerly; for while it was usual to require merely an average amount of floor space for each child, with a specific height for the room, it is now customary to determine the accommodation of a schoolroom by the number of children that can be properly seated in it, regard being had to the kind of desk and to the positions of the doors and fireplaces; and thus, in a room otherwise well suited for the purpose, much space may be sacrificed, so far as the number of children to be accommodated is concerned, owing to the arrangement of these details. This lost space is usually described as 'wasted,' but inasmuch as it tends to increase the otherwise very small quantity of cubic space available for each child, this term is hardly a desirable one. The requirements of the Education Department prescribe a width of from 18 ft. to 20 ft. or 22 ft. for a schoolroom, and state that if the width does not exceed 20 ft. groups of three long desks must be used, but if the width is 22 ft. dual desks, five rows deep, must be used. It is further stated that a length of 18 inches is to be allotted to each child on the long desks, with gangways 18 inches wide between the groups, and in the case of the dual desks, which are 40 inches long, the gangways between them need be only 16 inches. The height of the schoolroom must

be from 12 ft. to 14 ft. These dimensions give an average floor area of rather over 10 sq. ft. to each child, with cubic space of about 123 ft. (calculating the height at 12 ft.) In the case of workhouse schools, where the dormitories are sometimes placed above the schoolrooms—an arrangement which tends to fix a width of 18 ft. only for the schoolrooms—the amount of floor area and cubic space per child is slightly less, averaging about 9¼ sq. ft. and about 111 cub. ft. of space per child. In the case of infants' schools the Education Department are satisfied with a floor area of only 8 ft. per child, which gives scarcely 100 cub. ft. per head.

These capacities are obviously very small, and can only be justified on the supposition that the warming and ventilation arrangements are so complete that the air of the room will be *constantly* changed without creating draught and without unduly affecting the temperature of the room, whatever may be the condition of the external atmosphere. But unfortunately this is only a supposition, since in actual practice it is found impossible to ensure these important conditions, the more so as it is not usual to employ anyone possessing that interest in the subject and the practical skill which are indispensable for efficiently regulating the warmth and ventilation at all seasons of the year. The best alternative to this inefficient control of constant ventilation seems to be the provision of a larger amount of cubic space per child without unduly increasing the usual height for schoolrooms, and it cannot be too strongly urged that this should be generally effected. Mr. Charles E. Paget, Medical Officer of Health at Salford, in his 'Handbook on Healthy Schools'[1] advocates 400 cub. ft. of space per child as a minimum in elementary schoolrooms, and 800 in the schoolrooms of the great public schools. Where the schoolroom is of the requisite size for the whole number of children attending school, and class rooms are provided in addition, as is prescribed under the Poor-law requirements of the Local Government Board, it follows that a very substantial addition to the space per child is afforded in the schoolroom, since many of the children are absent from that room for considerable periods when attending classes in other rooms or undergoing industrial training, and the remaining children get the benefit of the additional space in the schoolroom.

The arrangement of windows for lighting the schoolroom should be such that the light should be admitted as much as possible on the left-hand side of the pupils. This is more particularly necessary in the classrooms. In any case it is important to avoid so arranging the windows that a strong light is admitted directly in face of the children, as this would aggravate any tendency to weakness in the eyes. A strong light behind the children is objectionable for educational reasons. From a hygienic point of view there is advantage in placing the desks in a schoolroom across the room, so that the children should sit with the windows on their sides, the windows admitting the strongest light being on their left-hand side, the other windows being adapted mainly for purposes of ventilation. The sills of the windows may, with some advantage, be at a higher level than is usually deemed desirable in ordinary day rooms, a height of 4 ft. or 4 ft. 6 in. above the floor being a useful average height for them in schoolrooms. They should, however, invariably extend up to within a few inches of the ceiling level.

In addition to the school and class rooms the residential school must include those other rooms which are necessary out of school hours in order that the children may be able to vacate the schoolroom at intervals for purposes of recreation when the weather does not permit of their being out of doors, and where they may pass the long winter evenings. Such rooms,

[1] *Health Exhibition Literature*, vol. i. London: William Clowes & Sons, 1884.

which are usually termed day rooms, should, according to the rules of the Local Government Board, afford floor area of at least 10 square feet per child, and be from 10 to 12 feet in height. This amount of space, however, is regarded by some authorities as very scanty. Mr. C. E. Paget urges the provision of space at the rate of 1,000 cubic feet per child, renewable at the rate of 2,000 feet per child per hour. These rooms should be well ventilated by windows opening into the external air in their opposite side walls, and are best situated upon the ground floor, so as to be ready of access to the playgrounds. Like the schoolrooms, they should have a solid floor of wooden blocks, and must be capable of being suitably warmed in winter. They ought not to be used by the children for taking their meals in, but a separate hall or dining-room, well ventilated and warmed, is indispensable for that purpose. The dining-room must be so arranged, as regards the domestic offices and its means of ingress and egress, that the food should be served to the children in a hot and palatable condition. It is a most unfortunate thing for the children if the food intended to be eaten hot is allowed to get chilled before it is served to them or before they can reach their seats and commence their meals. Such conditions are apt to lead to the food being wasted instead of being consumed by the children, and it may here be pointed out that the meals at boarding-schools are sometimes arranged at such considerable intervals that the children cannot be deprived of any portion of the food served to them without disadvantage.

In residential schools the dormitories are usually in the one and two pair storeys, and the arrangement generally ought to follow that prescribed for wards for the sick, with such modifications only as may be desirable under the different circumstances for which the dormitories are to be used. The usual width in the case of Poor-law schools is 18 feet, each bed, according to the requirements of the Local Government Board, having a minimum of 3 feet 9 inches of wall space, 36 square feet of floor space, and 360 cubic feet of air space. If the dormitories are 15 feet wide the wall space has to be increased to 4 feet. These amounts of space are certainly the least that could be allowed with propriety, but they are in excess of what was formerly considered requisite when, moreover, the children were commonly permitted to be placed two in a bed—an arrangement which is now prohibited. Dr. Clement Dukes, in discussing the subject of school dormitories at a conference at the Health Exhibition in 1884,[1] points out that a plentiful supply of sleep in dormitories affording ample and pure air, is as important to the young and growing as a plentiful supply of food, and he believes that, notwithstanding this, some 50 per cent. of the dormitories in the boarding-schools of Great Britain 'would be found to be as bad as they could possibly be, and 40 per cent. just passable, but nothing like what they should be.' He further points out as 'an incontrovertible fact' that in many of our schools there is less than 300 cubic feet of space per head in the dormitories.

In France, among the rules laid down for the construction and furnishing of normal schools by the *Commission des Bâtiments Scholaires*, it is prescribed [2] that the dormitories are never to hold more than thirty beds, are to have windows in their opposite side walls, are to be at least 4 metres high and $7\frac{1}{2}$ metres wide, that the space between the beds shall be at least a metre wide, and that as the beds are 80 centimetres wide each bed shall have a wall space of 1 metre 80 centimetres, and floor area of about $6\frac{3}{4}$ square metres and

[1] *Health Exhibition Literature*, vol. xi. London: William Clowes & Sons, 1884.

[2] *L'Etude et les Progrès de l'Hygiène en France de* 1878 *à* 1882. Paris: G. Masson, éditeur, libraire de l'Académie de Médecine, 1882.

about 27 metres of cubic space. The rules go on to prescribe that, where movable curtains to separate the beds are not adopted, the *Commission* recommend cubicles (*cabines*) at least 2 metres 75 centimetres deep by 1 metre 80 centimetres wide, with a central passage 1 metre 50 centimetres wide. If preferred, the cubicles may be placed in two rows against a central longitudinal partition with a passage a metre wide along each side of the dormitory. The partitions separating the cubicles are to be not more than 2 metres high, and raised at least 20 centimetres off the floor, and each cubicle is to be furnished with merely a bed, a stool, and a clothes-box. It is stated, however, that the system of cubicles is not generally adopted. Whether the cubicle system or the open dormitory is adopted, there is, according to these rules, a very large amount of space available for each pupil, and, as the cubicles are not furnished for use otherwise than for sleeping, they can be thoroughly aired during the day. It is perhaps hardly to be expected that so much space can be generally given to each boy or girl in school dormitories of institutions and inexpensive schools in this country, but as a general rule the amount of space afforded is very inadequate. Both Dr. Dukes and Mr. C. E. Paget advocate for our climate 800 cubic feet of space, with some 70 square feet of floor area for each child, it being urged that with less space it is often impracticable to ensure efficient ventilation without draught. Moreover, the beds must be kept at a sufficient distance apart in order to diminish the risk of any complaint or constitutional disorder being communicated from the occupier of one bed to that of the next bed. Dr. Dukes further expresses the opinion that from ten to sixteen beds in each dormitory is an appropriate number.

Upon the question of the advantages and disadvantages of the cubicle system opinions seem to differ, there being perhaps as many and as powerful advocates for the one system as for the other. That cubicles, except under very good general administration, are capable of abuse and may tend to prejudice the moral as well as the health condition of a school can hardly be doubted. Dr. Dukes regards them with much disfavour, and Dr. Alder Smith considers them 'an abomination in every way;' but on the other hand Mr. C. E. Paget, in his paper on Healthy Schools, already referred to, records his opinion as decidedly favourable to the cubicle system in well-managed schools. All authorities, however, agree in the necessity, from a health point of view, for the absolute prohibition of the use of the cubicles for purposes of study. In fact, no kind of occupation should be allowed in the dormitories or cubicles during the day. One important advantage of the cubicle over the open dormitory, however, is that it practically necessitates the provision of a greater amount of cubic space than where the beds are placed along the sides of an open dormitory, and where they may consequently be put closer together if the number of children to be accommodated renders it necessary. Where the beds have each only a very small amount of wall space it is practically impossible to avoid placing some of them immediately under the windows, an arrangement that should always be avoided as far as possible.

The flooring of dormitories for children should be of well-seasoned boarding, properly grooved and tongued, and whether stained or not should be polished with bees'-wax or paraffin. This is far better than that frequent washing and scrubbing which is so often effected in many schools, and which in damp weather is so difficult to get dry by the children's bedtime.

The question as to the best arrangements for purposes of ablution in the residential school is one which requires the most careful consideration, since the cleanliness of the skin is of such importance to the health conditions of the children. As regards lavatories it has been alleged, with much apparent

reason, that one of the means by which ophthalmia has been spread amongst the children in pauper schools has been not only by the use in common by several children of the same towel, but also by the wash-hand basins being imperfectly rinsed after use, so that secretions discharged from the diseased eyes of one child have been left in the basin, and been allowed to mingle with the clean water used by the next child washing at the same basin. Although this means of communication of disease has not been actually proved, its probability affords a strong *à priori* reason for guarding against such a possibility, and consequently not only have round roller towels been practically abolished in most Poor-law schools, but the use of ordinary washing basins in them, especially the larger schools, has been done away with, and an arrangement substituted by which each child washes at a running jet or spray of water, so that it is practically impossible for the same water to be used by more than one child. The water, which can be delivered at any required temperature, falls into surface channels on the floor behind slate slabs to protect the children from splashing, and experience has shown that the quantity of water consumed under this system can be so regulated as scarcely, if at all, to exceed that ordinarily used in wash-hand basins, while the children are able to thoroughly wash the whole upper part of their bodies. The system had been in use for many years at the Royal Military Asylum at Chelsea before it was adopted, some fifteen years ago, in certain Poor-law schools, but the details of arrangement have since been improved in various ways. The necessity for supplying hot water to children's lavatories is sometimes regarded as a needless expense, it being contended that such a luxury is not met with in the ordinary dwelling of other than the well-to-do classes. But it is at least necessary in the case of children of the low condition of vigour and vitality usually met with among the very poor, and accordingly in most pauper schools it has been found desirable to require an adequate supply both of hot and cold water, and it is recommended that the lavatory arrangements should be such as will admit of each child washing the hands, face, and upper half of the body at least twice daily. For this purpose it is requisite to provide jets, or basins where the running-jet system is not adopted, in the proportion of fifteen jets or basins to every hundred children.

With regard to the important question of baths for the children it is much to be wished that the practice of daily bathing for every boy or girl could be carried out in all schools. This, even in some of our best public schools, is regarded as impracticable, but the daily cleansing of the skin by means of cold bathing and friction has so many hygienic advantages that it is desirable to aim at this practice as nearly as the circumstances permit. For very young children, however, and children of the poor condition already referred to, the use of cold water at all seasons would hardly be right, and therefore, for those children at any rate tepid or warm baths should be provided. The regulations of the Local Government Board prescribe that the bathing arrangements in Poor-law schools should admit of every child being bathed at least once a week in winter and twice a week in summer, and certainly in other residential schools the facilities for bathing ought not to be less. Glazed fireclay baths, such as are made at Stourbridge, are among the best adapted for the purpose, as they are very strong, the surface is durable and can be kept clean without difficulty, and they do not require casing in. They absorb a certain quantity of heat from the water, but where they are used by a number of successive bathers, as is the case at schools, being of course emptied and recharged repeatedly, the loss of heat which occurs at first is not of much consequence. It is a wise precaution, in the case of baths to

be used by children, to have a movable key, or spanner, to the hot-water tap, to be kept in charge of the attendant, as otherwise accidents by scalding may occur. In all schools, whether for boys or for girls, the children ought to be taught to swim. At most schools some provision is now generally made to effect this most desirable object. Where the school is near the sea or on a suitable river, swimming therein is commonly practised in the summer months with great advantage to the children. During the winter, the children ought to have the opportunity of going to a public swimming bath, where the water is kept at a suitable temperature—say about 70° Fahr.—and this is done by arrangement in the case of many public and private schools in the provinces. But at numerous Poor-law schools and other similar institutions, swimming baths have been specially constructed for the use of the children with excellent results. One good bath, arranged so as to be available by the children of either sex, is far better than a separate bath of smaller size for each sex.[1] Mr. Paget, however, urges that in the interest of health, even where swimming baths are occasionally resorted to, the practice of daily cold-water sponging should still be encouraged as much as possible, and he adds that as physical health depends largely upon its being carried out, no school should be called a healthy school which does not provide some regular means for its accomplishment.

The next important point in connection with schools of the type under consideration is that of closet accommodation, and with respect to this it may at once be said that while the closets for night use must of necessity be attached to the building and in near proximity to the dormitories, those for general and day use ought to be wholly detached and out of doors. In the interests of purity of air within the building, the closets attached to the building must be arranged in the same way as is now universally required in the case of the closets of hospitals—i.e. they must be placed in projections from the building, provided with opposite external windows for the purpose of cross-ventilation, and must further be separated from the interior of the building by an intervening lobby, itself having independent cross-ventilation. Whatever form of closet is adopted, whether on one of the systems of dry-earth or on the water-closet system, it should be regarded as indispensable that this arrangement should be carried out. The requisite amount of accommodation in connection with the dormitories is never large, since, where the children are in good health, they are not often resorted to at night, but one closet ought at least to be readily accessible from each dormitory. The same projection may usefully contain the slop sink and housemaid's sink where the chamber utensils are emptied and thoroughly cleansed, for the slop sink, which receives a quantity of excreta, ought to be treated in the same manner, as regards its position and arrangement, as the water-closet. It is very desirable that the use of chamber utensils in dormitories should be abolished as much as possible, as the retention of them involves the exposure of a considerable surface, in the aggregate, of urine, which must tend, by evaporation, to vitiate the

[1] Mr. Ernest Turner, F.R.I.B.A., in his Report to the Social Economy Committee of the Paris International Exhibition 1889 (British Section) on Public Baths and Wash-houses, refers to a new system of heating the water at the baths of the Royal Military Academy at Woolwich, for which it is claimed that the whole of the heat generated is used, and a uniform temperature ensured. With this, he adds, may be combined a system of continuous forced circulation of the water through a purifying and aërating apparatus, by means of which the purity of the water may be maintained for a considerable period without great loss of heat. The cost of heating is thus reduced to a minimum, as cold water need not be introduced in the baths so frequently, and the cost of raising its temperature is avoided. The system is the invention of Mr. Charles H. Rosher, C.E., who has been assisted in reference to the purification of the water by Mr. A. H. Hobson, F.R.M.S., F.C.S.

atmosphere of the dormitory. In some schools for boys, urinals have been provided in suitable projections from the staircases and the children encouraged to use them night and morning, thus admitting of a great reduction in the number of chamber utensils in the dormitories.

For day use, out-door closets should be provided, and as these would be the closets generally used by the children they should not be unduly remote from the day and school rooms, nor should they be so placed that, in going to and from them, the children would be much exposed to the weather. It is indispensable that they should be well lighted after dark. This is requisite not only on the score of cleanliness and morals, but in order that the children may not shrink from going to them during the winter evenings. The number of closets needed for a given number of children is another point that calls for attention, since, if the number of closets is scanty, the children may be led to neglect or to be irregular in the use of them, and every effort should be made, in the interest of their health, to facilitate and encourage regularity in this respect. The Education Department prescribe the rate of closet accommodation as follows :

Number of children	Number of Closets	
	For Girls	For Boys
Under 50	3	2
„ 70	4	2
„ 100	5	3
„ 150	6	3
„ 200	7	4
„ 300	8	5 and urinals in proportion

But inasmuch as these numbers relate to day schools only, where it may be expected that a large majority of the children will have obeyed the daily call of nature before leaving home, it follows that a considerably higher rate of closet accommodation is requisite at the residential school. The Local Government Board have prescribed, for Poor-law schools, a rate of 10 closets per cent. for boys and 15 per cent. for girls—urinals being requisite in addition for the boys, and this would seem a proportion that may fairly be applied to residential schools generally.

The precise kind of closet best adapted for children will depend much upon the locality. If the institution is so situated that an ample supply of water and a proper system of sewers are available there can hardly be any question as to the advisability of adopting some kind of water-closet; on the other hand, where water supply and sewers are not available, the dry-earth system is undoubtedly the best. The privy in which the excreta are covered or mingled with coal-ash is much used in certain parts of the country, but in schools, where the consumption of coal and production of ashes is necessarily very small in proportion to the number of children using the privies, it is scarcely ever found to be a satisfactory system, the contents of the receptacle beneath the privy seat being generally in a wet and offensive condition. In country districts where the dry-earth system is in use, it is generally possible to obtain an ample quantity of suitable garden mould containing organic matter; with reasonable attention on the part either of those using the closets, or better still on the part of the school officers, who should take care that the proper quantity of properly sifted dry earth is thrown into the receptacle at

certain regular intervals every day, the system is an admirable one, and the contents of the receptacle may be retained undisturbed for a much longer period than is permissible in the case of a coal-ash privy. But whenever adopted it cannot be too strongly insisted upon that the necessary supervision, attendance, and appliances for keeping the closets free from nuisance will be regularly and duly supplied, otherwise the system cannot be expected to prove satisfactory.

As regards the details of construction, it is necessary to keep the receptacle, if fixed, wholly above the level of the ground adjacent, in order to preclude the possibility of surface water finding its way into it and rendering the contents unduly wet; for it is of the utmost importance that the contents of the receptacle should be kept as dry as possible. Where the receptacle is movable, as in the case of tubs or pails, the regularity of service and attention is not less important than in the case of the fixed receptacle, but greater frequency of removal becomes necessary, as the receptacle, being small for facility of manipulation, is sooner filled. Where water and sewers are available, the best kind of closet for outdoor use is that known as the trough closet, with a periodical automatic flush. These closets, when the trough is made of glazed stoneware of a light colour, can hardly be surpassed for cleanliness and suitability.

Every residential school ought to have a complete laundry of its own, so as to avoid the necessity for sending the soiled linen away to be dealt with, possibly in places that are already infected, or in which there are infected persons or things. The laundry building should be at a distance from the occupied school buildings, and ought to have a good drying ground, where the linen could be exposed to light and air whenever the weather permits. It ought also to have an efficient drying apparatus for use when the weather does not admit of the wet linen being dried out of doors; likewise a well-ventilated room for airing the finished linen after leaving the ironing and mangling room. Near the laundry there should be a good disinfecting chamber. Such a provision is an excellent precaution against the introduction of clothing and other articles suspected of infection. The best apparatus for the purpose is that in which the articles to be disinfected can be submitted to steam at high pressure so as to penetrate to the innermost parts of the article. There are two or three good kinds of disinfecting apparatus, but a detailed account of the efficiency of several kinds will be found in the official report (1885) on the subject by Dr. H. Franklin Parsons, one of the Medical Inspectors of the Local Government Board.

In separate Poor-law schools it is usual to include among the buildings a block of probationary wards, where children on their first arrival can be kept in some sort of quarantine until it has been ascertained that they are free from disease. The necessity for such wards has been demonstrated over and over again in the case of many complaints common to childhood and which are not always obvious in their early stages; but especially have such wards been found necessary in regard to ophthalmia. This subject is, however, referred to later in connection with school sanatoria.

WORKHOUSES

The English workhouse is an institution which, since it first became a necessity, has undergone at least as much change in arrangement, from a health point of view, as have hospitals and prisons. The importance of these Poor-law institutions is alone a sufficient reason for giving the subject special consideration; for in England and Wales there are some 650 unions and

Poor-law authorities, each possessing one workhouse, and many of them having several workhouses of one sort or another. In these are housed about 200,000[1] paupers, and the amount annually expended upon these buildings (irrespective of repairs), in altering and enlarging them and in erecting new ones, is about 500,000*l.* The old parish poorhouse, in which, under the direction of the overseers, the poor were formerly relieved, was bad in every conceivable way, and the whole system of the relief of the poor became so scandalous that, in 1834, Parliament passed the Poor-law Amendment Act, which, with certain further amending Acts, has been in operation ever since. Under that Act unions of parishes were formed and Boards of Guardians of the Poor were constituted; workhouses under responsible paid officers were provided, and the arrangements for the relief of the destitute poor were made uniform for the whole of the country. With the scanty knowledge that existed at that time in regard to all matters concerning health, it is not surprising to find that these early workhouses were exceedingly defective in their sanitary arrangements.

In a recent publication[2] upon the subject, some typical plans of the workhouses as recommended by the first Poor-law Commissioners are given, from which it will be seen that in one instance a workhouse for 500 inmates, upon a square site of one acre of land, is arranged so that the various wards are placed against the four boundary walls in such a way as to have no other ventilation than is derivable from the windows and doors on the inner side next the courtyard, and so that each inmate would have an average of only 131 cubic feet of space. In another plan, also for a workhouse for 500 inmates of all classes in the one building, the various wards certainly have means of through ventilation, but the inmates were in some cases placed in beds tier above tier, and in others two in a bed, while the amount of cubic space for the sick was scarcely 300 feet, and for those who were not sick only half that amount, and the closet arrangements within the building were, as may be expected, very defective. What the precise results of these conditions were it is difficult now to ascertain, but while it is probable that much sickness that we now know to be preventable was caused, and that an excessive mortality prevailed, it is obvious that the arrangements generally for the treatment of the sick were extremely unsatisfactory.

Some improvement took place in the later arrangements, but they were still very defective, and so serious had these conditions become towards 1864, that in the following year the proprietors of the *Lancet* newspaper started a commission of their own to inspect and report on the general state of the Metropolitan Workhouse Infirmaries, and in an introduction to the reports so made the *Lancet* said: 'The State hospitals are in workhouse wards. They are closed against observation; they pay no heed to public opinion; they pay no toll to science. They contravene the rules of hygiene; they are under the government of men profoundly ignorant of hospital rules.' The reports which appeared in the columns of that newspaper at intervals from the middle of 1865 to the early part of 1866 led to the appointment of a special official inspection of the workhouses by a medical inspector (Dr. Edward Smith, F.R.S.) and a lay inspector (Mr. Henry B. Farnall, C.B.), whose joint report was duly presented to Parliament. About the same time the Poor-law Board appointed a committee to inquire into, and report upon, the amount of cubic space that ought to be provided for the several classes of workhouse inmates, and one of the

[1] In 1888.

[2] *Knight's Guide to the Arrangement and Construction of Workhouse Buildings*, London: Knight & Co., 1889.

results of the agitation that had taken place was the passing of Mr. Gathorne Hardy's Act for amending the laws relating to the relief of the poor in the metropolis, an Act which constituted the Metropolitan Asylums Board and provided for the erection of separate hospitals and asylums for the reception of the harmless imbeciles who had previously occupied so much space and caused so much trouble in the workhouses, and also of paupers suffering from any of the dangerous infectious fevers.

Public attention all this time was being directed towards sanitary matters generally. The Royal Commission upon Barracks and Hospitals had reported; the Herbert Hospital at Woolwich and the Chorlton Union Hospital had been erected on the pavilion system; and much activity began to prevail in the improvement of workhouses generally throughout the country. The Poor-law Board in 1868 issued a set of printed rules entitled 'Points to be attended to in the Construction of Workhouse Buildings,' [1] in which the amount of space prescribed for each inmate in the several classes was fixed generally in accordance with the recommendations of the Cubic Space Committee. Separate infirmaries, independent of the workhouse of the unions to which they belonged, were erected in many of the larger unions and parishes, and were placed under the superintendence of competent medical men instead of as previously the medical staff being subordinate to the master of the workhouse. Separate schools were provided in the suburbs for the metropolitan pauper children, and likewise in connection with some of the large provincial unions. It will thus be seen that, while in the early workhouses the common arrangement was to place all the inmates, whatever their number and condition, in one huge building, under one roof, it is now the practice to provide separate buildings at least for the inmates in health and for the sick; while in the case of workhouses for more than a certain number of inmates, a separate building is usually provided for the children, unless they are wholly removed from the workhouse to some distinct and separate school. The regulations and requirements of the Local Government Board are very definite as to this subdivision of building, special stress being laid upon the necessity for avoiding the aggregation of large numbers of inmates in any single block. This important requirement is to some extent met by the equally important requirements, on administrative grounds, for the subdivision of classes, and accordingly a complete workhouse for a large union will ordinarily comprise the following distinct buildings:—

(*a*) Entrance building, including probation wards.
(*b*) Tramp wards.
(*c*) Main building for aged and able-bodied inmates in health.
(*d*) Imbecile wards.
(*e*) Children.
(*f*) Infirmary.
(*g*) Isolation sick wards.

But where the number of indoor poor is very large, some of these buildings take the form of distinct institutions. This is specially the case in the Metropolitan Poor-law district, where the children are provided for wholly in suburban schools, the harmless imbeciles in suburban asylums, and the infectious cases in special fever and small-pox hospitals.

The minimum amount of space prescribed for each pauper in the dormitories of the several buildings above referred to is as follows:

[1] Revised and reissued in 1891.

—	Wall space per bed	Floor space	Cubic space
	Lineal feet	Square feet	Cubic feet
Casual pauper, tramp or vagrant wards	3	27	324
Probation or receiving wards	–	40	400
Able-bodied and aged	4	36	360
Very infirm (bed-ridden)	5	50	500
Women with infants	5	50	500
Imbeciles	5	50	500
Children	3′ 9″ to 4	36	360
Ordinary sick and syphilitic	6	60	600
Lying-in cases	8	80	960
Offensive cases	8	80	960
Sick children	5 to 6	60	600
In isolation wards	12	144	2,000

In addition to the above, day-room space is requisite for certain classes, such as the casual pauper, who may be detained for a short period and whose sleeping accommodation may be in the form of a separate room or cell having a floor area of 36 feet and 360 cubic feet of space; also for the adult in health at the rate of 15 square feet of floor-space; for the imbecile at the rate of 20 square feet of area, and for children 10 square feet in addition to their school and class rooms and work rooms. For the sick, the re-

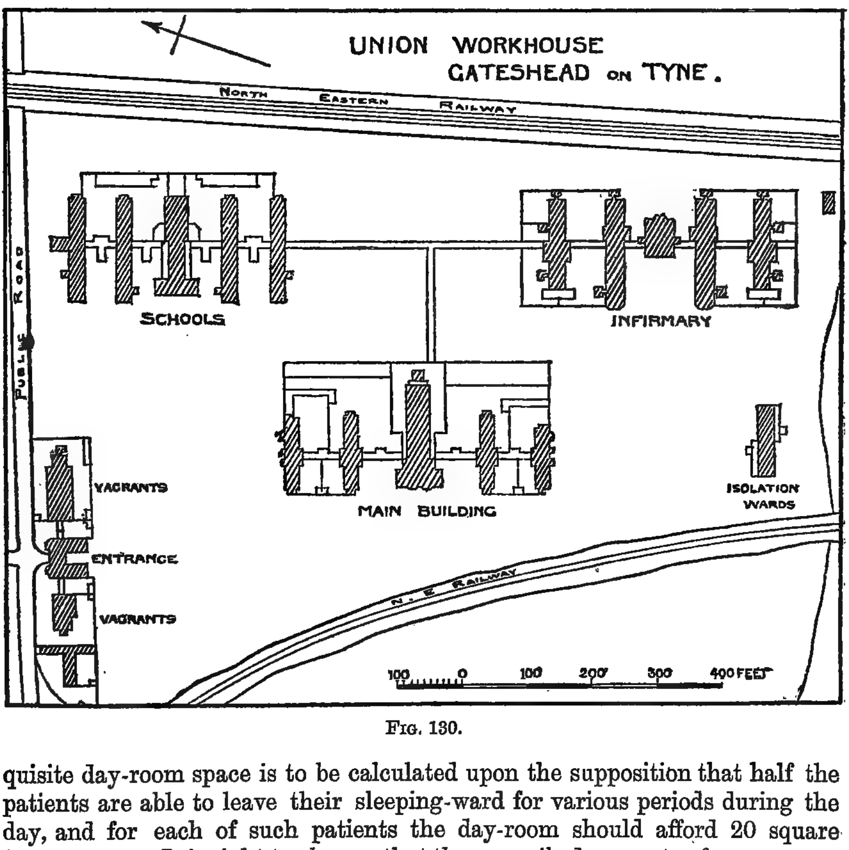


FIG. 130.

quisite day-room space is to be calculated upon the supposition that half the patients are able to leave their sleeping-ward for various periods during the day, and for each of such patients the day-room should afford 20 square feet of space. It is right to observe that the prescribed amounts of space, especially in the sleeping wards, are generally the smallest that can properly be regarded as sufficient, and, indeed, they are only so prescribed on the supposition

that the arrangements throughout for ventilation and warming are complete and efficient. As minimum quantities of space, they are in practice often exceeded, as would be the case, not only in times of prosperity, when the number of indoor poor is low, but where, as is often the case, the wards are constructed of greater width and height than the minimum dimensions prescribed in the regulations. In the case of the large sick wards of the metropolitan, and some provincial, modern Poor-law infirmaries the cubic space is invariably greater than the above amounts, since, while the amount of wall space is the same, the width of the wards, instead of only 20 feet, the minimum width prescribed in the regulations, is almost always 24 feet, and the height 12 feet, consequently an amount of about 850 cubic feet is available for each patient; this corresponds with the amount recommended by the Cubic Space Committee, and is the basis upon which the accommodation of these wards is calculated for computing the annual grant received by the Boards of Guardians in the London district out of the Metropolitan Common Poor Fund and the funds of the County Council of London under the Local Government Act, 1888. In the latter case the requirement as regards the provision of day-room space, as such, is dispensed with. As regards the hygienic arrangements of workhouse hospitals and schools, it will suffice here to refer to the pages relating to hospitals and schools generally; and as regards the other buildings of a workhouse, the principles ordinarily applicable to hospitals have to be followed. It will be seen from the annexed block-plan of the new and complete workhouse for the Gateshead Union (fig. 130), built from designs by Messrs. J. H. Morton, Newcombe, and Knowles, that what is known as the pavilion principle has been adopted for all the principal buildings. This institution affords accommodation for 916 inmates, classified as follows:—

	Male	Female
Main Building—		
Aged and infirm	92	66
Able bodied	32	62
Women with children	—	30
Married couples	12	12
Schools—		
Boys and girls	120	120
Infants	30	30
Infirmary—		
Imbeciles	25	25
Ordinary sick	66	66
Offensive cases	10	10
Itch and venereal	16	16
Lying-in cases	—	10
Isolation wards	3	3
Entrance building—		
Receiving wards	8	8
Vagrants	36	8

HOSPITALS

In considering the conditions that go to make a hospital healthy or the reverse, the peculiar circumstances attending the aggregation of a large number of sick or wounded persons under one roof need to be carefully borne in mind.

Hospitals, as charitable institutions, exist for the purpose of affording medical and surgical aid to the sick poor, and for economical reasons it is essential that a considerable number of patients should be treated together in one institution. Further, for economy of construction and nursing, it is necessary that the patients should be grouped together in general wards.

It is not, however, necessary for the benefit of the patient that he should form one of a group of some twenty patients in a ward, or of some four or five hundred patients in a hospital. On the contrary, it is distinctly an element of danger to the individual patient that he is one of a large number of diseased persons brought together under one roof.

Diseases arise *de novo* within the wards of a hospital, which are clearly traceable to direct contamination of air by wound surfaces, and are known as 'traumatic;' and the enormous sacrifice of life to the various forms of septic disease which took place in hospitals in former days, notably in the old Hôtel Dieu at Paris, shows very clearly the extent of the danger incurred from this cause.

The aggregation, therefore, of large numbers of diseased persons under one roof can only be justified if it can be shown that the advantages arising therefrom more than counterbalance the risks incurred. The advantages are twofold: 1st, to the patient, in that the highest possible skill in medicine, in surgery, as well as in nursing, is freely at his disposal, and that everything that science can suggest will be applied to restore him to health; and 2ndly, to society at large, in the incalculable value of the material for study and teaching presented in the wards of a large hospital.

The important factor, then, in hospital hygiene is that a hospital is a building which is perpetually producing within itself the elements of danger to its own inmates; 'an establishment which never rests from fouling itself; nor are there any products of its foulness—not even the least odorous of such products—which ought not to be regarded as poisonous' (Simon, 'Sixth Report of the Medical Officer of the Privy Council,' 1864).

The air of a hospital, then, is liable to contamination from the following causes:—

1. The emanations or effluvia from the bodies and excretions of the patients.

2. The presence of suppurating wounds, with their necessary dressings, poultices, &c.

3. Foul linen, bedclothes, &c.

The foregoing are necessary and unavoidable conditions common to all hospitals.

These conditions are aggravated, and their power for evil intensified by—

(*a*) Insufficiency of cubic space.

(*b*) Inefficient ventilation.

(*c*) Improper arrangements for the removal of excreta, dressings, poultices, soiled linen, &c.

(*d*) Faulty arrangement of buildings.

The neglect of proper measures of hygiene produces in a surgical ward the class of diseases known as 'septic'—e.g. erysipelas, pyæmia, septicæmia, &c., and, as it will be seen, it has happened over and over again that a hospital has become so saturated with the septic poison of recurrent outbreaks of disease that nothing short of total destruction has availed to stamp out the mischief.

In fever hospitals it has long been known that overcrowding in the wards is productive of the worst possible results, and that the roughest sort of shelter which admits of a copious through current of air is better than a permanent structure without adequate means of ventilation.

No more striking example of defects of construction and administration can perhaps be given than the old Hôtel Dieu of Paris. This remarkable structure occupied a site close to the Cathedral of Notre Dame, and extending to both sides of the river, the two parts being connected by two bridges, one

of which was in fact a ward. Writing in the year 1788, Tenon puts the total number of patients at 3,418, of whom 2,627 were in the buildings on the south side of the river. In this vast building, which was nothing more than one huge ward—so intimate was the intercommunication between the various parts—were assembled patients with fevers, small-pox, skin diseases, lying-in women, and surgical patients. 'In the middle are placed the most infectious departments, such as clothes stores, mortuaries, dissecting rooms; they [e.g. the patients] are contained in four or five floors of wards joined together and without ventilation, wards surrounded by rooms for the staff, which cool and shade them; where the staircases are insufficient; where the sole and only promenade is a place encumbered with drying grounds and linen in course of evaporation; a monstrous pile more fit to prolong sickness, to destroy than to re-establish and preserve health' (Tenon, 'Mémoire sur les Hôpitaux de Paris,' 1788).

The same authority gives the total number of beds provided for these 3,418 patients as 1,219, of which number 733 were 'grands lits,' and held six patients each! The remainder were single beds.

The condition of the latrines is described by the same author as mere masses of ordure: the latrines were wholly inadequate in point of numbers, and were in the closest proximity to the wards. The extent to which infection must penetrate into the wards is, says M. Tenon, inexpressible.

The immediate result of this state of things was, that one patient in every four and a half died, without reckoning the deaths of children born in the hospital and transferred to the 'Enfants Trouvés.'

The buildings of the Hôtel Dieu were to a large extent of great age, some portions dating back certainly to the fifteenth century, some possibly older still. They had been added to and enlarged from time to time without much definite plan, except to increase the number of beds; and the disasters consequent upon the inherent defects of the structure were intensified by overcrowding.

Of the conditions which have been referred to as aggravating the hurtful influences inseparable from a hospital ward, insufficiency of cubic space and inefficient ventilation are closely allied, and may be taken the one as the complement of the other. Cubic space, indeed, is of little value in itself unless it is accompanied by ample means of ventilation. The importance of this has received striking illustration on many occasions, notably during the Franco-Prussian War, when it happened that a church and a slaughter-house in Paris were about the same time turned into hospital wards for wounded soldiers. In the church gangrene broke out and the mortality amongst the men was very heavy. In the slaughter-house no septic disease at all appeared, and the men all made good recoveries. And this happened notwithstanding that the cubic space per man in the church was greater than in the slaughter-house. The essential point of difference in the two buildings was this. The slaughter-house was a mere shed, with the sides of louvre boards, and the men therefore were practically in the open air; whilst in the church the walls were of solid masonry, and the windows narrow, and with but few openings.

This experience is also amply borne out by that of the hut hospitals in the field during the same war. These huts were built of rough boarding, and of so light construction that the wind blew freely through them. Nevertheless, there was an almost complete absence of septic disease, while in the permanent hospitals, or the houses temporarily converted to the purpose, hospital diseases were of frequent occurrence.

Instances could be multiplied to any extent of the value of pure air to surgical patients; and the same remark applies equally to fever patients.

During an epidemic of typhus fever in Paris in 1814 the patients in the Abattoir of Montfaucon, situated in one of the highest parts of Paris, fared much better than those in the regular hospitals (Parkes). In the Irish fever of 1847–48 cases treated in the open air and in sheds made better recoveries than those in the permanent buildings (*ibid.*).

A notable instance of the mischief caused by the want of efficient ventilation is that of the York County Hospital. This building was designed to be warmed and ventilated entirely by mechanical means. There were no fireplaces and the windows were all fixed and were in some cases double. The air after being warmed by passing over hot pipes in the basement was driven into the wards by an engine, and the foul air was drawn out of the wards by heated shafts. This system remained in operation for nine years, by which time the persistent ill health of the patients, and particularly the constant occurrence of erysipelas after the slightest incisions, induced the authorities to abandon the artificial system and resort to open windows and fireplaces, and upon this being done erysipelas disappeared and the cases did well.

Improper arrangements for the removal of excreta &c. have been largely responsible for ill effects in hospitals. The evil effects of bad drainage were clearly recognised by Howard; amongst other things he recommends bringing a 'fine stream of water' to flush the drains at the Military Hospital, Dublin, and he notes with approval the method adopted at the Royal Hospital at Plymouth of flushing the drains by means of a tank holding 180 tons of water.

The necessity for the speedy removal of all fæcal matter from the proximity to any dwelling is doubly great in the case of a hospital ward, where perforce excretions are voided in the ward by patients unable to leave their beds, and where also the closets must be in close communication with the ward. In former days the readiest mode of making a water-closet was to cut off a small part of the ward by means of a boarded partition and within the space so enclosed to fix the apparatus. Except for decency's sake, the apparatus might just as well have been fixed in the centre of the ward. It is by no means the rule, even at the present day, to find the water-closets separated from the ward by more than a door or at least two doors; and the necessity for more effectual separation between the ward and the closet than is afforded by a door is not so invariably recognised abroad as it is in this country. In the late Mr. Netten Radcliffe's 'Report on the Sanitary Condition of the Manchester Royal Infirmary' ('Sixth Annual Report of the Local Government Board,' Supplement containing Report of the Medical Officer) he attributes the insanitary state of the hospital partly to the faulty arrangement of the water-closets. 'Few facts,' he says, 'are perhaps more clearly established in medicine than the mischievous influence of an atmosphere pervaded with sewer air in surgical wards. Now the water-closets, the baths, the ward offices, and the drains of the infirmary generally being placed within the building, several of the closets without even direct communication with the outer air, sewer air escaping from them must necessarily pass into the corridors and wards.' That the sewer air did actually make its way into the building, owing to the faulty construction of the drains, is clearly shown in a subsequent part of the report. The same writer found badly constructed drainage playing its part in the promotion of insanitary conditions at the Radcliffe Infirmary, Oxford (*op. cit.* Appendix, No. 5).

Besides the removal of fæcal and waste matters by means of drains there are the soiled linen, poultices, dressings, &c., of the patients, all of which are more or less infective and contain organic impurities which need to be quickly removed and destroyed. There is also the ordinary refuse (dust,

kitchen refuse, and so forth) which has to be disposed of. The accumulation of refuse matter in close proximity to the wards is an arrangement which involves very great danger to the inmates of the ward. In the report on the Radcliffe Infirmary, just referred to, Mr. Radcliffe notes the close contiguity of the laundry to the accident ward, and the practice of screening ashes and refuse immediately under the windows of the same ward as distinct elements in the causation of erysipelas in that ward.

Lastly, the inherent dangers of hospital life may be aggravated by improper arrangement of buildings.

The defects of planning are many; the most important are the close juxtaposition of blocks of several storeys shutting out the sun and preventing the free circulation of air; buildings in which the wards are so intimately connected that all the patients are practically in one and the same atmosphere; and buildings where there is direct atmospheric communication between the wards and the mortuary, out-patient department, or laundry. Years ago Miss Nightingale pointed out the defects of plans such as those of the Necker Hospital, Paris, and the Royal Free Hospital, London, in which a small courtyard is surrounded with high buildings on every side, impeding free circulation of air; of wards wherein the beds were placed along dead walls with windows only at the extreme ends, such as existed at the former Clinique de la Maternité, Paris; of Netley Hospital, and the Royal Hospital, Portsmouth; of wards such as those in the Old Marine Hospital, Woolwich, where there was 'no provision for ventilation worthy of the name, and the wards are so arranged that the sick must of necessity be supplied with common foul air.' ('Notes on Hospitals,' 3rd ed.)

The conclusions arrived at by Messrs. Bristowe and Holmes in the 'Report on Hospitals,' already referred to,[1] were by no means in favour of pavilion hospitals as opposed to the older type of plan; but it must be remembered that almost the only example of pavilion hospitals then in existence was the Lariboisière at Paris, in which the advantages of the pavilion system are to so large an extent neutralised by the great height of the buildings on the corridors. Strongly biassed as these eminent authorities undoubtedly were in favour of the older form of hospital plans, they yet unhesitatingly condemned the arrangement of a number of small wards on both sides of long corridors. Of this latter type the Manchester Royal Infirmary is an example, and its history unmistakably illustrates the evils incident to such a plan.

Professor Erichsen also condemns emphatically what he calls the 'big-house' plan, in which are 'basements containing kitchens, sculleries, cellars, and the ordinary offices of a large establishment; with an operating theatre and dead-house more or less closely connected with the main building; with every floor filled with sick and injured people.' ('Hospitalism,' by John Eric Erichsen, F.R.S., 1874.)

Enough has been said of the evils liable to arise in consequence of faulty construction; it now remains to consider what are the conditions necessary to be observed in the planning and construction of hospitals in order to insure that, so far as the structure is concerned, the patients shall be treated under circumstances most favourable to their recovery.

The term 'hospital' includes a great variety of institutions having for their object the treatment and cure of the sick. These institutions may be divided into two main sections of general hospitals and special hospitals.

The class 'general hospitals' will include all the hospitals which receive all sorts of medical and surgical diseases except infectious fevers and chronic

[1] Sixth Report of Medical Officer, Privy Council. (See p. 719, *ante*.)

incurable and mental diseases. It will also include the large and increasing class of buildings called cottage hospitals and the infirmaries built and administered under the Poor-law system.

Special hospitals include fever and small-pox, lying-in, consumption, children, incurable and chronic, convalescent, mineral water and sea bathing, eye, ear and throat, cancer, skin.

Into the question of the *raison d'être* of special hospitals it is not desirable in the present work to enter; the question is a complex one and belongs more to the region of medical ethics than to that of hygiene. This much may be said, however, that of the necessity for special hospitals for fever and small-pox, and for convalescents, no reasonable doubt exists, whilst very strong reasons exist for special hospitals for children, incurables, and perhaps phthisis. From the point of view of hygiene the hospitals which need special consideration are those of the infectious class, and hospitals for consumption, children, and convalescents. The rest are governed by the general principles of hygiene applicable to all hospitals, and need not here be separately considered.

I. General Hospitals

Site.—'An ideal site for a hospital,' says Dr. Mouat, 'would be one where the conditions of soil, subsoil, drainage, water supply, and all surroundings were most free from local causes of impurity, and where there were fewest buildings and habitations to exclude or intercept air and light, or to be themselves active agents in the creation of causes of unhealthiness, such as factories, workshops, &c.' ('Hospital Construction and Arrangement,' Part I.) Such conditions are not always easily to be fulfilled when the hospital in question happens to be one in a large town, or if fulfilled in the beginning are apt to be greatly modified with the lapse of time and the growth of population. In London, the Middlesex and St. George's Hospitals are cases in point. When first established, in the first half of last century, both these institutions were in the outskirts of London as it then was, with open fields all round them. Now, though St. George's Hospital has the advantage of being close to two large parks, London has grown around and beyond both of them, until the outskirts are miles away.

A general hospital, again, must always be placed within a reasonable distance of the population whose needs it has to serve, so that in fixing upon the site for a hospital in a large manufacturing town regard must be had to the distance which patients would have to travel from the centres of industry, where accidents would be likely to occur. The importance of a free air space round about a hospital is very great, and a site completely shut in by high buildings is undoubtedly an unsuitable one. Dr. Mouat, in the work quoted, recommends a zone of aëration in extent equal to at least double the height of the buildings surrounding it; and modern practice on the Continent tends not only to confirm, but to go beyond this limit. The following table, extracted partly from a paper in the 'Practitioner' ('Notes on Modern Hospital Construction,' by P. Gordon Smith, June, 1888), illustrates the importance attached by authorities abroad to large site area per bed:—

	Approximate area of site per bed.
	Feet
Germany:	
Friedrichshain, Berlin	1,713
Tempelhof (military)	1,308
Moabit	1,144
University, Halle	1,575
University, Heidelberg	1,070

	Approximate area of site per bed.
France:	Feet
Bourges (military)	1,600
St. Eloi, Montpelier	1,615
St. Denis	1,685
Belgium:	
Antwerp	1,126
United States:	
Johns Hopkins, Baltimore	1,679
England:	
St. Thomas's, London	660
Great Northern Central	293
Middlesex	273
St. George's	166

In several of the hospitals in the foregoing list the very large proportion of site area to bed is due to the fact that the ward pavilions are all limited to one storey; a mode of construction that has not found very much favour in England, and owing to the great value of land is scarcely ever likely to be adopted in London or the larger provincial towns.

Where it is possible to exercise discretion in the choice of a site, regard should be had to the following conditions: The site should be sheltered from the prevailing rainy winds of the district, and, if such exist, from unhealthy winds also; a gentle slope is usually preferable to flat ground, and the side of a hill to the bottom of a valley. Undrained clay soils, or thin strata of gravel overlying clay, are both soils of an undesirable nature.

General Arrangement.—The disposition of the several parts of a hospital in relation to each other necessarily depends greatly on the size of the hospital and on the form and area of the site. But the important aim to be kept in view is the effective separation of the wards from the other parts with due regard to economy of construction. The pavilion system was undoubtedly a step in advance on the old 'big house' plan; but in its inception it was regarded entirely as a means of obtaining more effective ventilation to the wards, and had no reference to the separation of parts. It is, indeed, no uncommon thing to find a large pavilion hospital, of comparatively modern date, the lowest floor of one pavilion occupied by the laundry, while in another is found the out-patient department. Even the mortuary and *post-mortem* room are not infrequently to be found occupying a portion of the lowest floor of a ward block.

In order to arrive at some general principles of planning, it is necessary to consider what are the essential parts of a general hospital.

In every hospital of whatever size there must always be—

(*a*) Administration offices. These comprise the official rooms, i.e. board room, secretary's office, steward's office, &c.; the domestic offices, i.e. kitchens, larders, sculleries, storerooms, and the sleeping accommodation for resident staff and servants.

(*b*) Wards and their offices.

(*c*) Operation room, or theatre, with subsidiary rooms attached.

(*d*) Out-patient department.

(*e*) Mortuary and *post-mortem* room.

To these will be added in the case of very large hospitals—

(*f*) Laundry.

(*g*) Medical school.

(*h*) Nursing home.

In several recent examples of hospitals abroad each one of the depart-

ments has been placed in an absolutely separate and distinct building, in some cases unconnected by even covered ways. At Heidelberg, for example, the University Hospital consists of sixteen distinct buildings, five of which are devoted to surgical patients, one to eye patients, four to medical cases, and one to skin cases; the rest comprising the administration block, pathological institute, mortuary, kitchen, and laundry. The ward pavilions are connected together by covered ways, consisting merely of roofs supported on posts, and quite open at the sides.

Very similar to the last is the Hôpital de l'Isle, or Insel Spittal, at Berne; but here there are no covered communications.

At the Johns Hopkins Hospital, Baltimore, the various buildings are all detached, and there are no connecting corridors.

The drawbacks to this mode of arrangement are: (1) the great extent of land necessarily occupied; (2) the greater proportional cost involved both for land and buildings; and (3) the increase in cost of administering such a building consequent upon the greater distances between the various parts.

The really essential parts of such a building may be summed up as follows: (1) separation, or at any rate avoidance, of intimate connection between the wards and the administration block; (2) separation of medical from surgical wards; (3) absolute atmospheric disconnection between the wards on the one hand, and the mortuary, laundry, and out-patient department on the other.

To fulfil these conditions by arranging a series of one or two storey buildings on a plot of ground of such ample dimensions as that of either of the three hospitals mentioned is simple enough, but in London and in large towns where land is of great value such a plan becomes a practical impossibility, unless, indeed, it is contended that the beneficial results to the patients are of such value as to justify the enormously increased cost.

That the essential parts of the system can be obtained without so lavish an extent of land being required is evidenced by the plan (fig. 131) of the new Great Northern Central Hospital, London. This hospital occupies a site of less than a third in extent of that at Heidelberg. Nevertheless, it will be seen from the plan that the wards are practically isolated from each other and from the rest of the hospital; that the operation room is, though in easy communication, not in direct atmospheric connection with the wards; that the mortuary and the out-patient departments are distinct and separate buildings.

So far, then, the essential principles of the separation of parts are complied with in this plan with a comparatively small area of site per patient.

The value of a sufficiency of open space about a hospital is undoubtedly very great; but in cases where the cost of land is so great as it is in London and some provincial towns the absolute necessity for so large an area of site per bed may reasonably be questioned. And although the proportion of site to patients at the Great Northern Central Hospital is by no means what it might be without undue extravagance, yet it must be admitted that even on this restricted site it has been possible to obtain the essential conditions of separation of parts.

Administration Block.—The general arrangements of this part of a hospital will necessarily vary with the size of the hospital. In a large building the offices will be numerous and the residential part extensive; but the modern custom of housing the nursing staff in a separate building very much reduces the amount of accommodation to be provided in the main administration block. In some modern hospitals also the kitchen offices, with the dormitories for servants, are placed in a separate block, thus still further reducing

the main block. In the majority of English hospitals the administration block comprises the secretary's office or offices, boardroom, residences for

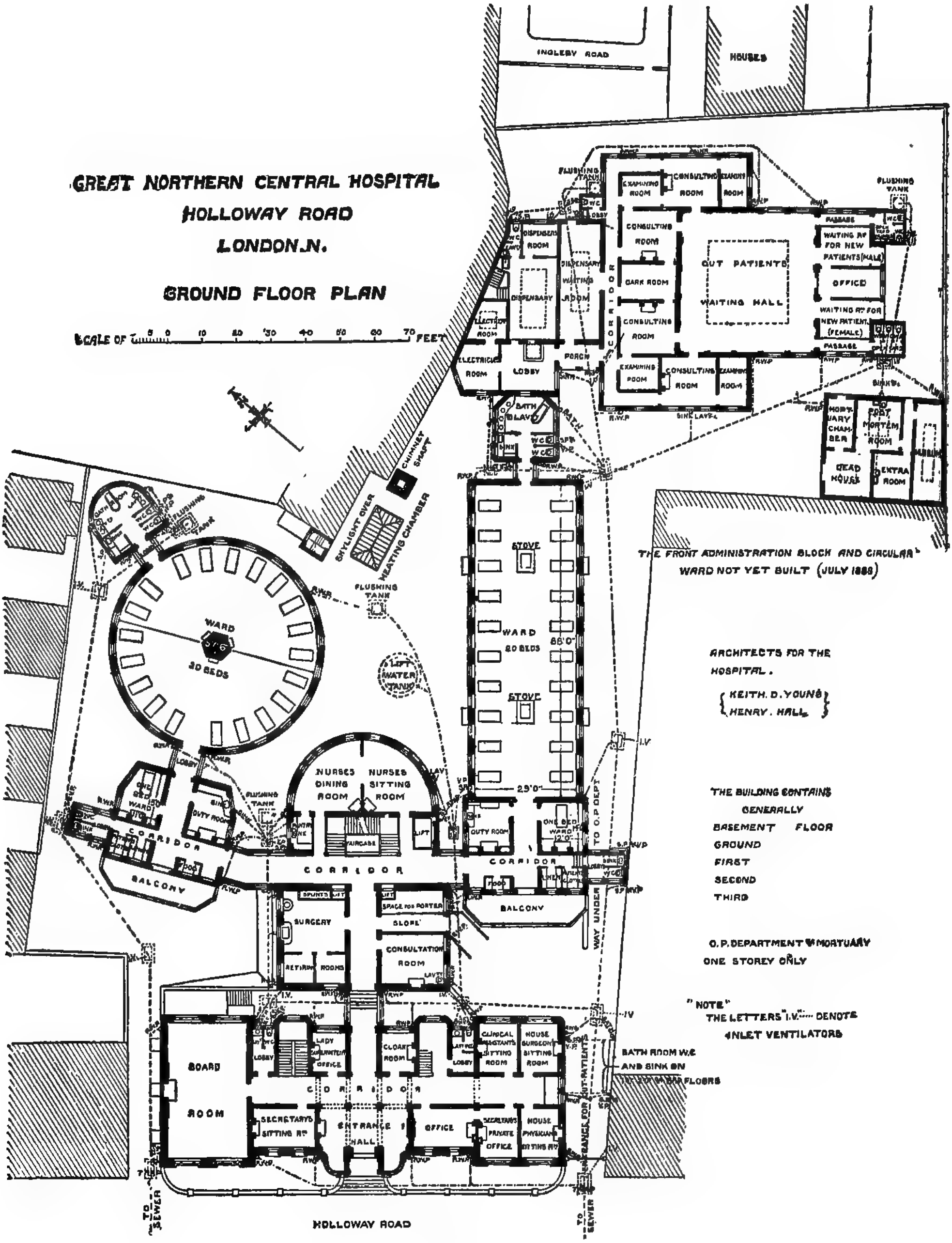


FIG. 131.

medical staff, matron and secretary, steward's office, storerooms, kitchen offices, and servants' dormitories. To these should be added an office for the matron, and a consultation room for the visiting staff. The kitchen offices

should be placed on the top floor, and the stores in the basement, with communication between the two by means of a lift and speaking-tube. Separate dining-rooms must also be provided for the male and female servants.

Wards.—It is now pretty generally agreed that the pavilion type of ward is the most suitable one for general hospitals, but the precise form of the ward admits of variations. The most general form is that of a rectangle varying from 20 to 30 ft. in width, and from 30 to over 100 ft. in length. Two other forms exist—one the circular, the other octagonal. The circular form has been adopted in several instances, and its merits will be discussed later ; of the octagonal form only one example exists, that at the Johns Hopkins Hospital, Baltimore.

The dimensions of a ward are governed by two conditions: (1) the number of patients to be associated together, and (2) the cubic space and floor area to be allotted to each patient. It is impossible to lay down any hard-and-fast rules for the number of patients to be put into one ward. Consideration of nursing economy points to large wards. Consideration of hospital hygiene points equally to small wards. From the former point of view a convenient number for a ward is thirty-two, which number will be found at Lariboisière, the Herbert Hospital, and Leeds Infirmary. On the other hand, at the newest hospitals on the Continent the average number in a ward will be found to be about sixteen. There can be no doubt that, especially for surgical wards, the smaller the number of patients associated together the better. A large number of small wards gives greater facilities for classification of cases than a small number of large wards. The question is, however, very largely one of cost, and it cannot at present be said with absolute certainty that the gain to the patients in small wards more than outweighs the additional outlay involved.

Having determined the number of beds in each ward, it is necessary to provide that each patient shall have sufficient space both of floor and of air. What constitutes ' sufficient ' space depends upon the question of ventilation. And by ventilation is meant such a change of air to each patient as will secure to him a constant supply of the purest available air without draught, and at a proper temperature. This supply should, according to the best authorities, be practically unlimited, or perhaps it would be more correct to say that it should be capable of unlimited increase when occasion demands. The figures for floor space and cubic space in general hospitals considered necessary by Drs. Parkes and De Chaumont are 100 to 120 ft., and 1,500 to 2,000 ft. respectively. General Morin gives 60 to 70 cubic metres (2118·6 to 2471·7 ft.). The Paris hospitals have a mean of 43 cubic metres (1518·33 ft.), while the London hospitals, according to the same authority, average 52 metres (1826·12 ft.) per bed. The latter figure is misleading, inasmuch as some of the large hospitals (Middlesex, St. George's, St. Mary's, Westminster) are entirely omitted from the list upon which the average is made.

As a practical deduction from these and like facts, it will be found that 100 square feet is the minimum floor space in general wards, and that this amount should be increased for acute surgical cases and for clinical wards.

In the latter case space is required for the students who gather round the beds for clinical instruction. At the Edinburgh Royal Infirmary—one of the largest medical schools in the United Kingdom—the floor space is 149 feet per bed, and at Halle—also a large teaching centre—it is 140 feet ; on the other hand, the floor space at the Johns Hopkins Hospital, on the planning of which an immense amount of thought and care has been bestowed, is only 105 feet.

With regard to cubic space, 1,500 feet should certainly be taken as the minimum for acute cases, though for wards in which a proportion of mild or convalescent cases are mixed with others of an acute nature the cubic space may with safety be as low as 1,200 feet.[1] In certain cases 2,000 feet will not be found excessive ; and in some instances, as at Edinburgh Royal Infirmary,[2] Antwerp,[3] Heidelberg,[4] Halle[5] (surgical wards), Hôtel Dieu (Paris),[6] St. Denis,[7] Bichât,[8] St. Eloi,[9] Genoa,[10] this amount is largely exceeded.

The requisite amount of cubic space must, however, to a large extent depend upon the means of ventilation adopted ; and it may safely be said that with our English habits of constantly open windows and open fireplaces a less amount of cubic space is permissible than when the mechanical means of ventilation so largely prevalent abroad are adopted.

It will thus be seen that no hard-and-fast rules can be laid down either for floor area or cubic space per patient, but that the amounts to be provided must be dependent on circumstances.

The particular form which a ward should take may either be rectangular, circular, or octagonal.

The rectangle is the most familiar form, and being most simple in construction has been until quite recently universal. The idea of a circular ward owes its origin in this country to the late Professor Marshall, F.R.S., who in 1878 suggested its adoption in a paper read by him at the Social Science Congress of that year[11] and subsequently published. Curiously enough, the same idea had about the same time occurred to a Belgian architect, M. Baeckelmans, who in 1872 submitted plans for a new civil hospital at Antwerp, which were with some modifications subsequently carried out.

Professor Marshall's advocacy of the circular form was based on (*a*) freedom of frontage to all points of the compass, (*b*) great accessibility to light and air, (*c*) greater area contained within a given length of wall in a circle than in a rectangle, (*d*) superior ventilability, and (*e*) more equal warming. He also considers that a circular ward can be better administered and would present a more cheerful and agreeable appearance than a long straight ward. The opponents of the system asserted on the other hand that a circular ward would be dark or inadequately lighted, that it would be difficult of supervision, that the patients would be uncomfortably in view of each other, that the ventilation would be difficult if not impracticable, and finally that the construction would be excessively costly.

While it is not yet possible to speak positively on the relative advantages of circular and rectangular wards, it is certain that the objections cited above have in practice been entirely disproved. In all the circular wards yet erected the question of lighting, ventilation, and supervision have been dealt with most efficiently, and no complaint has ever yet been made by the patients of any discomfort arising from the form of the ward.

The objections on the score of cost have been entirely based upon a fallacious system of argument, which presumed that no ward should ever hold less than twenty-eight patients. It is easy to show that the circular form is extravagant and indeed impracticable when the number of patients

[1] Le Fort, *Note sur quelques points de l'hygiène hospitalière en France et en Angleterre*, 1862.

[2] 2,015 to 2,039 ft. [3] 2,525 ft. [4] 2,050 ft. [5] 2,207 ft.
[6] 2,222 to 2,411 ft. [7] 2,457 ft. [8] 2,205 ft. [9] 2,328 ft.
[10] 2,644 ft.

[11] *On Circular System of Hospital Wards.* By John Marshall, F.R.S. With remarks and illustrations by Percival Gordon Smith. London, 1878.

in a ward passes a certain limit; but it is a *reductio ad absurdum* to first fix the limit at an impossible number and then condemn the system on that ground alone. Doubtless the construction of a circular building is more costly than that of a rectangular one, the conditions of each being identical except as to form; but judging from the very few examples that have yet been erected it may safely be said that the difference in cost need not exceed about two per cent. It is curious to note that the opposition to the circular system has emanated almost entirely from architects and not from medical men.

Circular wards exist at the following hospitals: Antwerp (Civil Hospital), Greenwich (Miller Memorial), Hastings, Burnley (Victoria Hospital), Liverpool (Royal Infirmary), Milton near Gravesend (Military), Seaforth near Liverpool (Military), New York (Cancer), and the Workhouse Infirmary, Hampstead.

The rectangular pavilion ward is of two forms: (1) the double ward (fig. 132), which consists of two ordinary wards placed side by side, with the dividing wall pierced at intervals with arches, and having four rows of beds between the two external walls: examples of this ward may be seen at St. Bartholomew's, the London Hospital, Guy's Hospital, and the London Fever Hospital; in a modified form at King's College Hospital and in some Poor-law infirmaries. (2) The ordinary single ward (fig. 133), which is varied only in size and in the arrangement of the beds. The latter are either placed in pairs against the piers dividing the windows, as at St. Thomas's, London, Tenon Hospital, and the Hôtel Dieu, Paris; or singly, having a window intervening between each bed and the next. The latter arrangement is much to be preferred, as it more effectually isolates each patient from his neighbours, and permits of equal spacing of the beds. No bed ought to be nearer to the next one than five feet; then each patient will have a minimum of eight feet clear wall space. In large wards for acute cases, this space ought to be increased to ten feet.

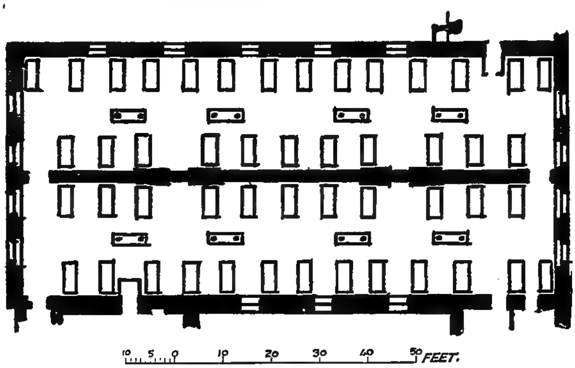


FIG. 132.

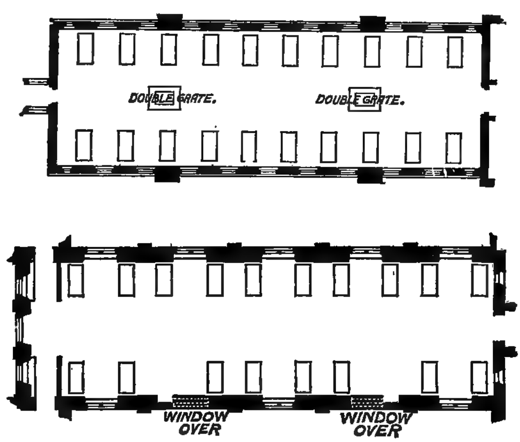


FIG. 133.

From what has been said it will be seen that a ward should have two rows of beds, and that between each bed and the next there should be a window. As usually arranged, this would give in a ward for, say, twenty beds eighteen

windows, nine on each wall. Therefore, at each end of the ward there would be two beds with a window at one side only. The practical result is that the space occupied by these end beds is not so well ventilated as the rest of the ward, and it has been often observed that the cases treated in them do not fare so well as those in the remainder. The remedy for this is to place an additional window between the end of the ward and the end bed on each side, increasing if necessary the length of the ward in order to do so, and giving the extra length entirely to the end beds. Thus, in a ward of twenty beds there should be twenty-two windows instead of eighteen. These end windows need not be as wide as the other windows, but may be just sufficiently wide to obtain the necessary movement of air.

There is no better form of window for a ward than the ordinary double-hung sliding sash with a hopper light above. The glass line should be sufficiently low to allow the patients to see out of window without standing up, and the top of the window should be as near the ceiling line as it is possible to get it. The lower sash should be furnished with a deep bottom rail, and on the sill should be fixed a deep board instead of the usual shallow bead. The lower sash can by this means be opened, and a current of air with an upward tendency admitted between the upper and lower sash, without any direct draught at the sill level. The part above the transome should be hinged at the bottom, and made to fall inwards to an angle of about 60°, and the sides protected with glazed cheeks to prevent down draught.

The amount of window area should bear some definite proportion to the cubic space of the ward. It is not very easy to give any definite rule for this proportion, which will be applicable to all wards alike, but in practice it will be found that a foot of window surface to from sixty to eighty feet of cubic space is a useful proportion to work upon. Dr. Thorne Thorne considers that in a well-constructed and efficiently warmed building the amount of window surface should not vary much beyond these limits, and that a proportion of one square foot to seventy cubic feet is, as a rule, the most advantageous. The failure to maintain sufficient warmth, and at the same time to properly ventilate the wards of the Children's Hospital at Pendlebury, is attributed by Dr. Thorne Thorne to the excessive proportion of window surface to cubic space, which at that hospital amounts to one foot of window surface to thirty-five feet of cubic space.

In exposed situations it is desirable to provide additional protection against loss of heat by radiation by glazing the windows with two sheets of glass, with an interspace of about three-quarters of an inch between the two.

The most suitable material for the surface of the walls of a ward would be one which should present an absolutely impervious washable surface without joints, and not liable to crack. Supposing it were possible to cover the walls entirely with glass without joints, such a surface would be without doubt an absolutely perfect one. Such a thing is, however, impossible. Various modes of approximating to such a result have been suggested; amongst others, marble, glazed bricks and tiles, and polished Parian cement. Marble walls, if the slabs could be got in sufficiently large sizes, would be excellent, but can hardly be regarded as practicable because of the excessive cost. Glazed bricks and tiles are the next best substitutes, but in both cases there is the objection of the numerous joints and the impossibility of getting a perfectly even face. Polished Parian cement was at one time thought to be a perfectly impervious surface, but experience has shown that it is scarcely, if at all, superior to ordinary plaster, while much more costly. Until some process is discovered by which a plastered surface can be rendered impervious

and washable, the best way to treat the walls of a ward is to form a dado of cement of a height that can be reached by the hand, and to paint and varnish the surface; above that to finish with ordinary plaster and distemper. The varnished surface can be washed in the ordinary course of ward cleaning, and the distemper can and ought to be renewed yearly.

The construction of a ward floor ought always to be what is known as fireproof; that is, of iron beams or joists embedded in concrete. Upon the surface of the concrete the wooden floor, formed preferably of oak or teak, should be laid solid. Apart from the fire-resisting nature of this construction, in itself an element of importance in a hospital, the advantage is gained of there being no space underneath the wooden floor to harbour accumulations of decaying organic matter, and each ward is more effectually cut off from the ward above and below.

An important point to observe in every part of a ward, as indeed also in other parts of a hospital, is the strict avoidance, as far as possible, of all projections, ledges, or angles in which dust can lodge. Thus all the corners of the panels of doors and the panes of window sashes should be moulded instead of square, and no mouldings or recesses (called by carpenters 'quirks') should be permitted. The vertical and horizontal angles of the walls, ceilings, and floors should likewise be rounded, and the same rigid avoidance of corners should be observed as far as practicable in the furniture.

Ward Offices.—Certain rooms, which for convenience sake may be grouped together as ward offices, must be placed in immediate contiguity to the ward. These offices all have their part in the economy of the ward administration; upon their completeness will depend much of the comfort and regularity with which the ward is worked.

The duty room, or ward kitchen, is a room in which the plates, cups, and saucers, &c., used in the wards are kept and washed, and in which a certain amount of invalid cooking is done. If there be no separate nurses' room attached to the ward, the duty room is the place where disinfectants, and sometimes medicines, are kept, but these should always be under lock and key, and in charge of the head nurse or Sister.

A nurses' room is, by some authorities, considered a necessity; in most older hospitals there is a bedroom and sitting-room combined attached to each ward for the head nurse, but many eminent authorities consider that while on duty a nurse's place is in the ward, and that when off duty she should be entirely removed from the ward atmosphere. From a health point of view the latter arrangement is undoubtedly correct, and if a nurses' room be provided near the ward, it ought certainly to be a sitting-room only, and not a bedroom.

These two rooms should of course be at the corridor or entrance end of the ward, and may be provided with windows overlooking the ward, though the practical utility of such appliances is questionable.

One or two small wards or rooms for one patient should in large hospitals be arranged at the corridor end for cases requiring special treatment, or such as for some reason would be better treated alone than in a large ward.

In close proximity to the duty room should be a linen cupboard for the store of ward linen, a cupboard for patients' own clothes, and a small larder for milk, bread, &c. All these should be properly ventilated and lighted. There should also be provided a suitable place in which to stand the coal trolley, the food trolley (for bringing meals from the lift), and a wheeled basket for dirty linen. These seem trivial details, but the importance of thinking of these things beforehand and providing for them is not slight.

The water-closets for the patients and the sink-room are usually and

most conveniently placed at the further end of the ward. In many cases also the bathroom is likewise at the same end. It is of importance that the atmospheric connection between the ward and the water-closets should be severed as completely as possible, while at the same time access to these offices must be easy and direct. To effect this it is necessary to interpose between the ward and the closets a lobby having windows on each side for 'through' or 'cross' ventilation. At each end of the lobby is a door, and by this means the air from the closets cannot easily be blown or drawn into the ward.

In America it is usual to place the water-closets at the entrance end of the ward and to rely wholly upon mechanical ventilation appliances to prevent a flow of air from the closets to the ward. This plan has the advantage of leaving the other end of the wards free for balconies or sun rooms ; but in this country, where natural ventilation is universally used, such an arrangement is impracticable.

The proportion of water-closets to patients should not be less than one to ten, and in none but very small wards should there be less than two closets.

The sink-room should be large enough to hold a good-sized slop-sink with a sink for cleaning vessels, a draining board, shelves and racks for bedpans and other crockery, and brooms. A cupboard having free ventilation to the outer air, and a door as nearly air-tight as possible, should be constructed in this room for keeping vessels in which fæces or urine have to be temporarily preserved.

The bathroom need not of necessity be separated from the ward by a lobby ; neither is there any special advantage in placing it at the same end as the water-closets. Besides the bath, it should contain lavatory basins in the proportion of about one to every five or six patients. The bath should be so placed that a patient can be easily lifted in and out, and carried to and from the ward in a recumbent position. For these and other reasons the bath should have its foot only to the wall.

Balconies and Barrack Wards.—The treatment of patients in the open air is much more resorted to on the Continent and in America than in this country. In most German hospitals there are covered balconies in which patients are kept during the summer months by night as well as by day. In America the 'sun room' at the end of the ward is a common feature. The 'baraque,' as it is used in Germany, is an institution practically unknown here. It consists of a wooden-framed hut raised about eighteen inches or two feet, or sometimes more, from the earth or brick piers. The spaces between the upright posts are protected by curtains only, which are drawn at night or by day to keep off the sun or rain. The patients, therefore, are practically in the open air ; such a 'baraque' exists at the hospital at Basel, and is devoted entirely to children (surgical patients only), who are kept there day and night from May to October.

Operation Room.—The operation room will vary in size according to circumstances, from the small room, just large enough to hold the table with the necessary adjuncts, to the theatre of a large clinical hospital, with its tiers of seats for students numbering often some hundreds. In large hospitals there are usually one or two minor operation rooms, in addition to the large theatre. These smaller rooms are specially needed for eye operations, for which a light at a special angle is necessary, and which cannot be performed in a theatre lighted entirely from the top. They are also needed for ovarian cases, when these are treated in a general hospital.

The operation theatre ought to be separated as completely as possible from the wards and the other parts of the hospital. The absolute isolation

of the operation theatre is by some surgeons considered so important that in some foreign hospitals—as, for instance, at Chartres and at Friedrichshain, Berlin—it forms an entirely detached building, and patients have to be conveyed thither in a hand ambulance through the garden.

This, perhaps, is carrying the principle to an extreme point; the operation theatre ought, however, to be so placed that atmospheric communication between it and the wards and the domestic offices of the hospital is entirely precluded.

The same precautions to ensure absolute cleanliness must be taken as in a ward, and everything of an absorbent nature should be as far as possible discarded. At the hospital referred to above (Chartres) the walls, floor, and ceiling are of cement, the window sashes and doors are of iron, the tables and shelves for instruments are of glass on iron supports, and the operation table itself is of zinc and iron. The operation room at the Derbyshire General Infirmary has the walls lined with marble to a height of seven feet, above which they are cement. The floor is of marble mosaic, the door and windows of iron, with the frames flush with the wall, and the tops to the sink and lavatory basins of glass. In fact, so far as the structure and fittings of the room are concerned, everything should minister to the condition of perfect asepticism, so necessary to be obtained.

Immediately adjoining the operation theatre there should be a surgeons' room, a room for the administration of anæsthetics, and, if possible, a small ward for the reception of a patient whom it is not desirable to move back to the general ward immediately after operation.

Out-patient Department.—Three things are necessary to the orderly working of a large out-patient department: (1) a spacious and well-ventilated waiting-hall, where patients can be grouped and classified according to their cases; (2) a sufficient number of consulting rooms readily accessible from the waiting room; and (3) a dispensary with small waiting-room attached, so placed that patients do not have to re-enter the main waiting hall after they leave the consulting rooms. The whole of the department must also be on one floor only, and entirely detached from the main buildings of the hospital. A reference to the plan of the out-patients' department of the Great Northern Central Hospital (fig. 134) will make these points clear. The entrances are separate for each sex, and the two small waiting-rooms are arranged just within each entrance for new patients to wait their turn for registration. Old patients pass straight into the large waiting-hall, where they are sorted out into groups according to their cases.

The consulting-rooms are four in number, and to each is attached a smaller room for examining patients. There is also a dark room for ophthalmoscopic work. After a patient has been seen by a medical officer he passes into the corridor at the back, and thence into the waiting-room beyond, where he waits his turn in a *queue* for getting to the dispensary window. This may be taken as a fair example of an out-patients' department in a moderate-sized hospital with no medical school attached. In the large clinical hospitals the consulting-rooms would have to be greatly enlarged in order to afford space for the students. In smaller hospitals a less number of consulting-rooms would suffice.

Mortuary.—It is of even greater importance that the mortuary should be a detached building than the out-patients' department, but it does happen that in very crowded situations it is impossible to afford room for a detached building at a sufficient distance from the ward windows; in such a case the mortuary ought certainly to be relegated to the top of the building, and communication should be made by an outside staircase and lift. The

mortuary should include, besides the room where several bodies may be kept at one time, a small chamber where one body at a time can be viewed by friends, and which may take the form of a mortuary chapel.

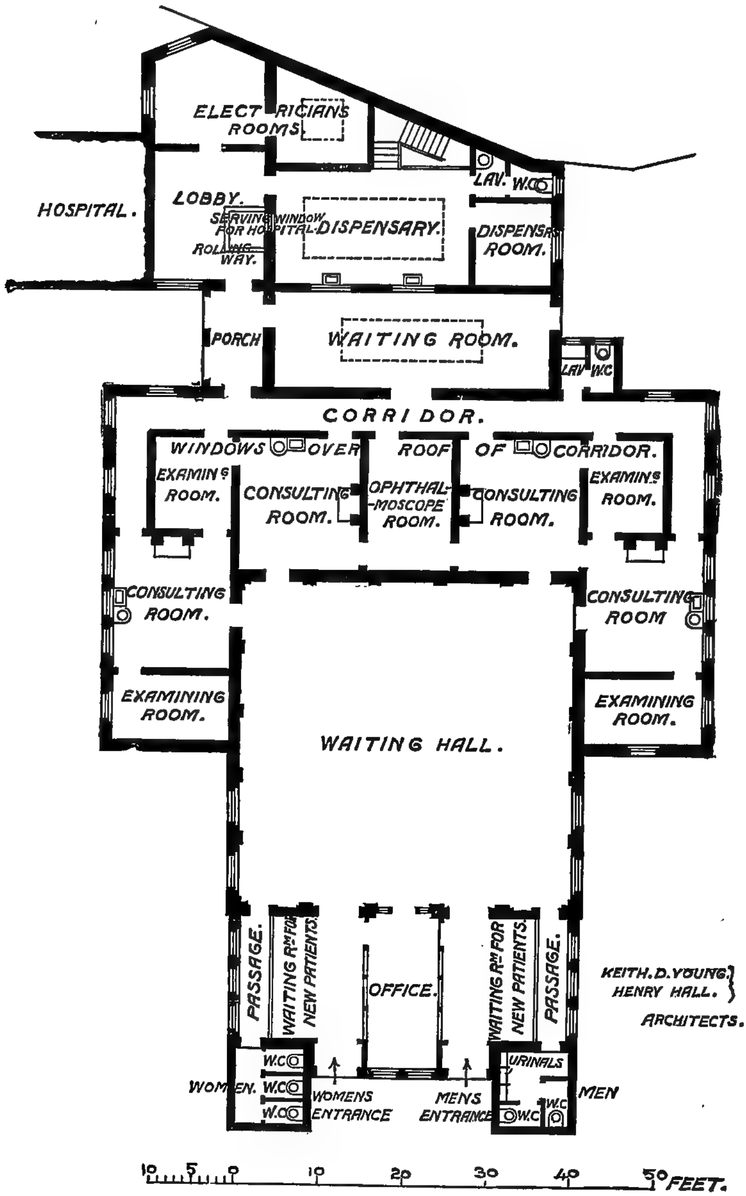


FIG. 134.

Attached to the general dead-house, but having no communication with the smaller room, should be the *post-mortem* room, and in the smaller class of hospitals with no medical schools there should also be a room for the pathologist and a small museum.

The *post-mortem* room must be top lighted, and should have a floor of some impervious material, made to fall to a channel under the table. The walls should be lined with glazed bricks or tiles, the table should be of marble

on an iron frame, and the shelves should be of the same material. A large and deep sink must be provided, and the waste-pipe therefrom must be treated in the same way as a soil-pipe. An efficient trap should be fixed immediately under the sink, and the pipe taken out through the wall into a vertical pipe, which must be carried up to its full diameter as a ventilator.

Examples of Hospital Planning

I. *Large General Hospital with Medical School, University Hospital, Halle, Germany.*—This large and important hospital was commenced in the year 1876 and completed in 1884. It consists of sixteen separate buildings, thirteen of which form the hospital proper, the other three being devoted to teaching purposes. The general disposition of the buildings is shown on the block plan (fig. 135).

The central block, A, with its four wings, is the surgical house. The central building is two storeys in height, with a basement, and the out-patients'

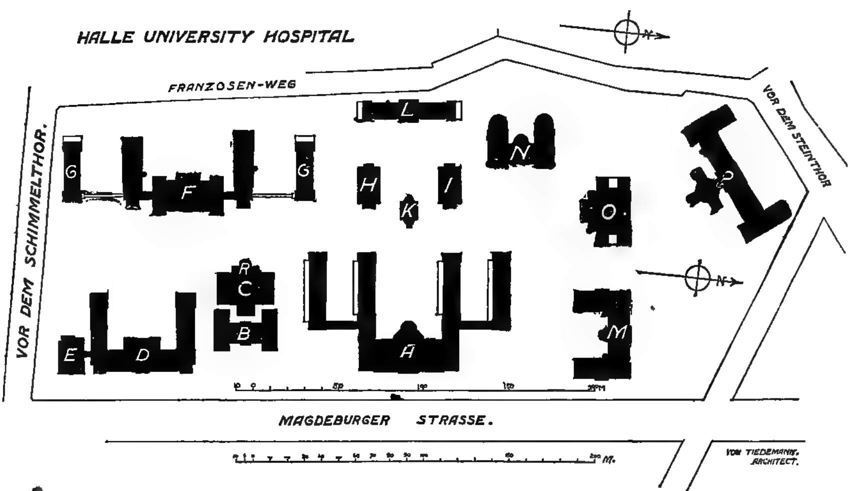


Fig. 135.

department, operation room, and rooms for the director and the resident medical staff. On the upper floor are also some small wards for two, three, and four patients each. The wings are one storey only in height, and contain each a ward for twenty-four beds, with duty room, nurses' room, lavatory, bathroom, and water-closets. These wings are raised about eight feet above the ground, and the part under the wards is entirely open. At the ends, under the duty room and the other ward offices, the basement is utilised for storage purposes. The floor space per bed is 142 feet; and the cubic space 2,210 feet. The beds are arranged in pairs opposite each pier, and a space of about ten feet, with a window, intervenes between the end bed on each side and the end wall of the ward. The floor is finished with terrazzo, a mixture of small pieces of marble and cement ground to a smooth surface and polished. The water-closets are, as is usual in Germany, connected with the ward by an ante-room or passage, and no attempt is made to separate them from the ward air by means of cross-ventilated lobbies. The walls are formed of timber framing, filled in with brickwork and covered inside with boarding. On the south side of each ward is a broad verandah, with steps leading down into the garden.

These wards, in common with all the rest of the buildings, are warmed

by steam, the pipes for conveying which are carried round the walls behind the beds. Ventilation is provided for in summer by open windows and a ventilating lantern on the apex of the roof, and in winter by an underground flue connected with the furnace shaft of the boiler-house for carrying off the vitiated air, and by openings in the outer walls of the ward for admitting fresh air below the steam coils and pipes.

The two buildings B and C are respectively the kitchen block and the engine-house. The kitchen block is four storeys in height, and contains, besides the kitchen with its scullery, larders, and other appurtenances, the laundry and bedrooms and day rooms for servants and officers.

The engine house contains, besides the boilers and machinery, a disinfection house fitted with a steam-disinfection apparatus.

Block D contains the gynæcological department, and has accommodation for eighty patients in wards varying in size from one to six beds each. Here are also rooms for students and medical staff, operation room, lecture room, and apartments for the midwife.

Block E is the director's house.

Block F, with the detached blocks G G, comprises the medical department. The central block with its two wings is two storeys in height, besides a half-sunk basement. The basement floor of the central block is devoted to rooms for porters and other men servants. In the basement of the wings are four wards for syphilitic patients, two in each wing; and in each wing a room for lunatic patients, with a padded room attached.

The ground floor of the central block contains the out-patients' department, with rooms for laryngoscopy, electrical apparatus, and for examination of patients, a large lecture hall, and rooms for the director and assistants. The upper floor contains some small wards for children, quarters for resident staff, registrar's rooms, and library.

In each wing there is on the ground floor a ward for twelve beds, a smaller ward for three beds, and two private wards for paying patients (one bed each). This arrangement is repeated on the first floor.

The detached blocks G G are very similar in arrangement to but smaller than the surgical pavilions. The wards are for sixteen beds only, and there is in addition in each pavilion a separation ward for one bed. These pavilions are raised above the ground about 3 feet; the flooring of the wards is of deal, and the walls are of brick plastered inside. The floor space is 135 feet, and the cubic space 2,033 feet per bed.

Blocks H I are two-storey buildings, described as 'extension' pavilions. They contain on each floor a ward for twelve beds, a small ward for two beds, and the usual offices. These pavilions are intended for medical and surgical cases respectively.

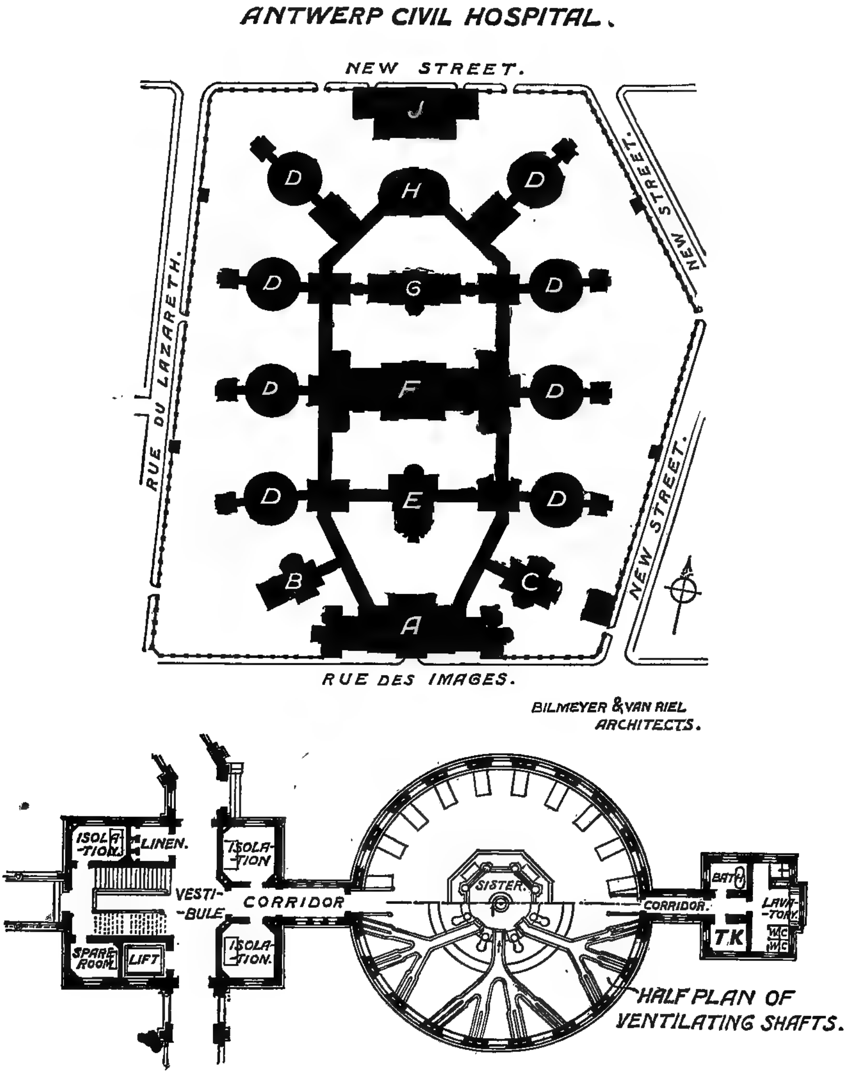
Block L is a one-storey pavilion divided centrally by the entrance, duty room and nurses' rooms, and contains two wards for twelve beds each, one for male, the other for female cases, and is used for isolation purposes. At each end is a separation ward for one bed. The floor space per bed is 128 feet and cubic space 1,925 feet.

K is the chapel.

M is a two-storey building with basement, devoted to patients suffering from diseases of the eye and ear. The basement is occupied by rooms for the porters &c. and storerooms. The entrance is in the centre on the north side; the wing to the right of the entrance contains the eye wards, that to the left the ear wards. In the central part are rooms for the director and assistants, operation theatre and lecture hall, and nurses' rooms. The wards are arranged for six beds each.

N is the pathological institute, O the physiological institute, and P the anatomical institute; R is the icehouse, and Q a building in which the sewage of the whole hospital is disinfected before passing into the town sewers.

The buildings occupy a site of some eight acres in extent.



PLAN OF A WARD PAVILION.

FIG. 136.

Civil Hospital, Antwerp.—This hospital (fig. 136) is the largest and most complete example of the circular ward system yet erected, and it is also specially interesting in having been the first instance in which the circular form was adopted.

The site upon which the hospital stands is nearly ten acres in extent, and is bounded on all four sides by public streets. The large area of the site enabled the buildings to be disposed in such a fashion that the space between the various blocks is extremely ample. The large block (A) at the entrance in the Rue des Images contains the director's and almoner's residence, porter's

lodge, and rooms for medical students, servants, &c. The corridors for communication with the ward pavilions lead off from each side of the central block of the front building. Proceeding along the western corridor, the small building marked B contains the operation room, with its two adjoining rooms for the surgeons and surgical appliances and two wards for one bed each. The corresponding building to this, C, on the east side, contains the mortuary and *post-mortem* room, with workshops below. Separated from this by a small enclosed yard is a coachhouse, stable, and coachman's dwelling.

The blocks marked D are the ward pavilions, and are all arranged on the same plan. Each pavilion is two storeys in height, and has cellars under the whole. The corridor is one storey only between the pavilions, with a basement which serves as a subway for communication between the wards and the laundry, and also for access to the ventilating shafts under the wards. On the ground floor, on the side of the corridor further from the ward, is the main staircase, a secondary staircase leading to the roof, a lift for patients, a separation ward, and a room in which are shoots for refuse and for dirty linen, and a recess in which the pipes for water, gas, &c., are arranged; on the other side of the corridor are two separation wards for one bed each. From the building which contains all the above accommodation a covered-in bridge leads to the main ward. This bridge, like those that connect the ward with the water-closets, is only about half the height of the ward itself. By this means the movement of air around the ward is much freer than it would be if the bridges of communication were carried up the whole height of each storey. The wards are 61 ft. 6 in. in diameter, and about 17 ft. in height. They each contain twenty beds, at which number the floor space per bed is 148·5 ft. and the cubic space 2524·5 ft. The actual number of beds, however, in each of these wards is twenty-four, which reduces the floor area to 123·7 ft. and the cubic space to 2103·7 ft. In the centre of each ward is an octagonal space partitioned off with a glass screen some 8 ft. high, and used as a Sister's room. The intention of this room appears to be that the Sister should use it as a sitting-room when on duty, and that the various appliances and drugs used in the wards should be kept there. The exact centre of the ward is occupied by the exhaust shaft for foul air, while at each of the right angles of the nurses' room is a shaft for the supply of warm air. The floors of the wards are laid with oak boards, wax polished, and the walls are plastered with a composition of gypsum and lime. The warming is effected by means of hot air, which is forced into the wards by a fan in the engine-house passing in its way over coils of steam pipes, and can be discharged either at the floor or the ceiling level as desired. The central shaft, already referred to, is provided with steam coils at its base, in order to warm the air and, by its expansion, produce an up current. The separation wards are also warmed and ventilated on the same system.

The small projecting block to each pavilion contains a *tisanerie* or tea kitchen, bathroom, lavatory, two water-closets, and two sinks.

Block E is the chapel, which is connected by an open passage with the main corridor of communication; the flat roof over this passage affords means of communication between the upper floor of the wards and the gallery of the chapel. Block F contains the kitchen offices and the dispensary and drug store; also dining rooms for male and female convalescents, attendants, and servants. Block G is the house for the Sisters of Mercy, with the linen store and lint store. Block H at the further end is the bathhouse. Here, as is common in large Continental hospitals, are, besides ordinary baths for both sexes, a Turkish bath, shower bath, two vapour baths, and two sulphur baths. The detached block, J, at the extreme

north of the site, is the laundry, and washhouse, used also for the washing of all the other hospitals in charge of the communal authorities of Antwerp.

A 'Barrack' or Hut Hospital. The Municipal Hospital at Moabit, Berlin.—This hospital (fig. 137) was erected in 1872 by the city authorities of Berlin for the purposes of an epidemic, but it has since been utilised for the reception of patients suffering from all kinds of diseases, including such infectious fevers as typhus and small-pox. The site is a long narrow parallelogram of about nineteen acres in extent, and having its longer axis north and south. At the south end are situated the administration buildings: A, porter's lodge; B, offices and residence for staff; C, kitchen; D, engine and boiler house; E, disinfection house; F, laundry; G, G G, stables and stores; H, fire brigade depot; I, ice-house; J, isolation wards.

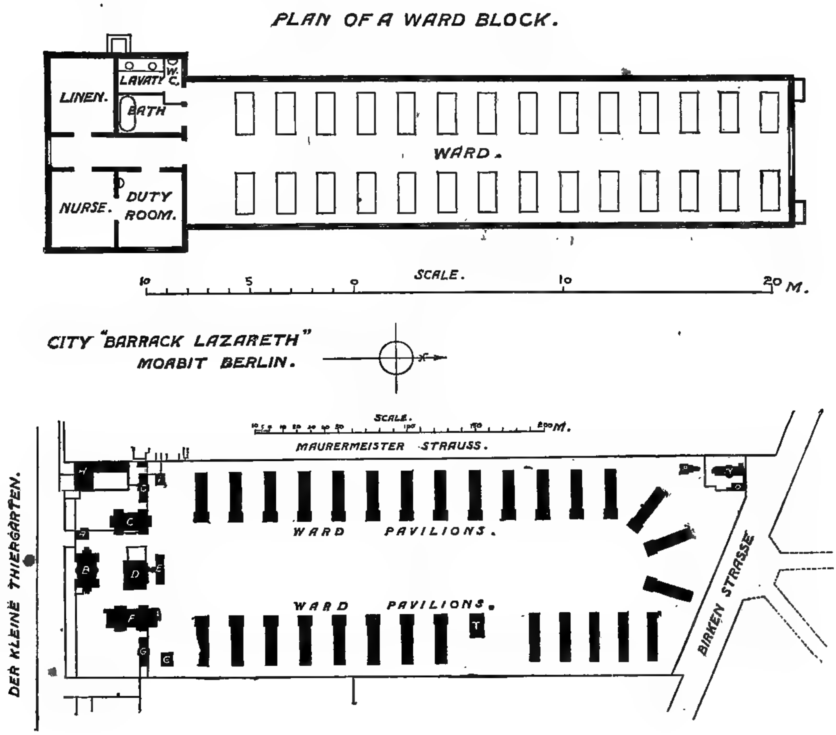


FIG. 137.

The ward pavilions, twenty-four in number, are ranged round both sides of the site. Each pavilion is entirely isolated from the others, and the space of about 56 ft. intervenes between. The pavilions are all of one storey, are constructed of timber framing filled in with stone, and lined on the inside with painted boards. The floors are composed of a species of concrete (*béton*), finished with a smooth surface of cement. The roof projects about 6 ft. on each side, and is formed of a double layer of planks grooved together, painted on the inner side, and on the upper surface covered with asphalte. At the entrance of each pavilion is a nurses' room, duty room, room for the temporary storage of dirty linen, and a bathroom and a water-closet; the two latter are entered directly from the ward, and in the water-closet are two apparatus. Each ward contains twenty-eight beds, with a floor space of about 69 ft. per bed and a cubic space of 864 ft. At the apex of the roof is a long

ventilator, and at the end of each ward are large folding doors, which are constantly open in summer. In the extreme north-west corner of the site are the mortuary (N), waiting hall (O), and shed (P) for burning clothing &c. which has been exposed to infection.

A Provincial Hospital with no Medical School.—Lincoln County Hospital (fig. 138), designed by Mr. Alexander Graham, has been selected as a good example of a provincial hospital of average size. It has accommodation for 105 beds. The general plan is in the form of an H, with projecting buildings on both sides of the cross stroke. The upright strokes are occupied by the wards, which are two storeys in height. The ground floor of that half of the western wing which lies to the south of the cross stroke of the H is devoted to the out-patients' department, which is thus placed in very intimate connection with the wards, the only serious blot on an otherwise excellent plan. The buildings projecting at front and back of the cross stroke contain the administration offices, the operation room, accident room, and some small wards for eye cases. The large wards are each 88 ft. by 26 ft. 6 in., those on the ground floor being 14 ft. and those on the first floor 16 ft. high. The beds are arranged in pairs between each window. The floor space per bed is 115·2 ft., and the cubic space 1613·7 ft. on the ground floor and 1844·3 ft. on the upper floor.

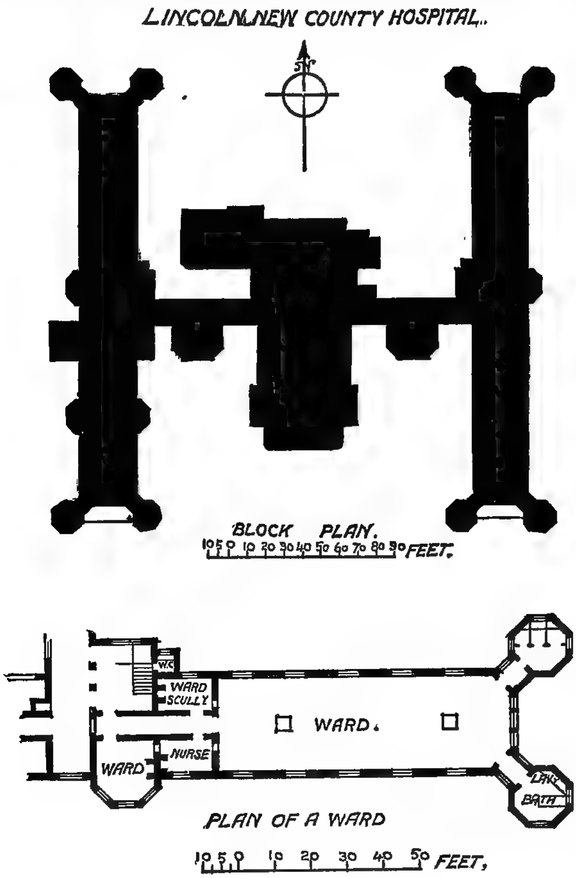


Fig. 138.

Tollet System. Municipal Hospital, St. Denis.—The system of hospital construction of which the new Municipal Hospital at St. Denis is an example is the invention of M. Tollet, an engineer of eminence.

The special peculiarity of the system is the form which M. Tollet adopts as the section of his wards. A transverse section of a ward is in the form of a Gothic pointed arch. The grounds upon which this form is adopted are that it is said to lend itself more readily to efficient ventilation, to prevent stagnation of air, and to present the minimum of surface for absorption. Other characteristics of M. Tollet's plans are the limitation of all wards to buildings of one storey only, the complete isolation of the several

pavilions one from the other, the adoption as far as possible of non-absorbent surfaces, and the avoidance of all angles, the use of fire-resisting materials, the adoption of natural means of ventilation, and the use of balconies and open space beneath the wards. Obviously none of the foregoing are the invention or the speciality of M. Tollet; but the thoroughness and skill with which he has recognised the advantages of and combined all these features are noteworthy indications of the progress of hospital hygiene in France.

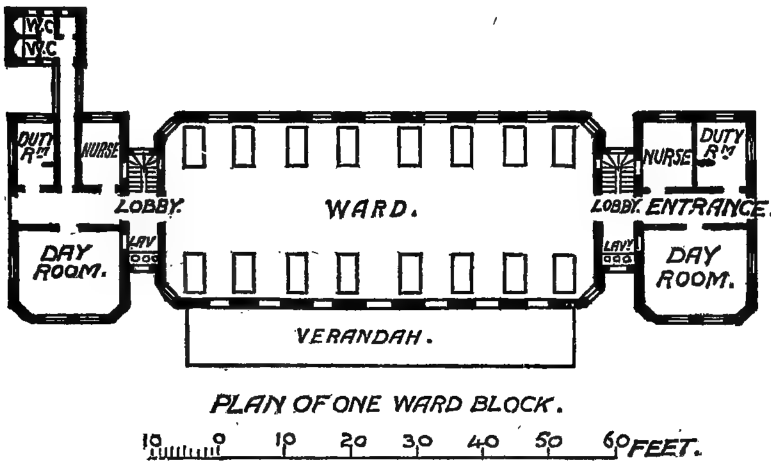


FIG. 139.—Hospital of St. Denis.

The pointed-arch form adopted by M. Tollet necessitates the provision of a very much larger amount of cubic space per bed than is usual or under ordinary conditions necessary. But as an essential part of the system is that the outlet for foul air is at the apex of the roof, the ordinary rule by which any access of height over 12 feet is disregarded would seem not to be applicable in this case. It must, however, render necessary greatly increased warming power.

Whatever may be the special merits of the pointed arch, of this there can be no doubt, that the general arrangements and the structural details of the hospitals designed on this principle are immensely in advance of anything that had preceded them in France.

The Municipal Hospital at St. Denis was designed by M. Laynaud, architect, and, in addition to its being a good example of the Tollet system, is in itself interesting as a type of a modern French provincial hospital.

The site is of an irregular shape, and situated just outside the old town of St. Denis, close to the glacis of the Fort de l'Est. Its situation ensures that it will never be surrounded by buildings.

The buildings (see fig. 139) are arranged in detached blocks, there being no covered communication between them, except in the case of two wards for the same class of diseases being coupled.

The building to the east of the entrance contains the boardroom and offices, and the kitchen offices, stores, &c.; that to the west contains the residences for staff and the dispensary. The two buildings to the east and west of the above-mentioned two blocks are for aged women and men respectively. These form the Hospice.

Of the five blocks forming the central row of buildings, the two at the extreme ends are the medical wards, those to the east being for women, those to the west for men. Each block contains two wards for sixteen beds each and two small wards for two children each. In the centre is a day room, with duty room, nurses' room, and the usual offices. It is noteworthy that here, as in all hospitals constructed on M. Tollet's system, the water-closets are separated from the wards by cross-ventilated lobbies. The three pavilions in the centre are for surgical cases. Attached to each medical pavilion is a bathhouse, in which are, besides two ordinary baths, the vapour and douche bath usual in Continental hospitals. Beyond the bathhouse on the male side is the laundry. The two small blocks north of the surgical pavilions are for the isolation of infectious diseases; behind them is the chapel, and at the apex of the site is the mortuary.

The large wards each contain sixteen patients. The floor space per bed is about 112 ft. and the cubic space 2,457 ft. The ends of the wards are rounded off at a large radius, and in the centre of the curve at each angle of the ward is a small window. The wards are raised upon piers above an open basement storey which is used as a subway of communication from one ward to the other, and in which the *calorifères* for warming the wards are placed.

A Workhouse Hospital.—Perhaps in no department of hospital construction has so great an advance been made during the last twenty years as in the infirmaries belonging to large parishes or unions. From being a department of a workhouse, and provided with accommodation often of the most unsuitable nature, the Poor-law infirmary has now come to be recognised as a hospital needing properly arranged buildings and a well-equipped and properly trained staff. The large institutions built by several metropolitan and provincial unions, as, for instance, St. George's Infirmary, Fulham Road; St. Marylebone, Notting Hill; Manchester Workhouse Infirmary, and Chorlton Union Infirmary, are examples of the improvement that has taken place in recent years. Many of the buildings in question present obvious defects of arrangement, such as a too close proximity of buildings one to another and the piling one over another of many storeys of wards. These, however, in view of the very great improvement in general arrangements, are defects of minor importance.

In the building illustrated (fig. 140) these defects appear to a less degree than in many others. The site is a fairly ample one, and the buildings are well separated. The plan is a very simple one, and consists of four ward pavilions, each three storeys high, a central administrative block, a detached wash-house, and a mortuary. The ward pavilions are connected with each other and with the administrative block by a corridor which is enclosed at the

sides on the ground floor, but is an open arcade on the first floor. At the entrance is a porter's lodge and a small block of receiving wards.

Cottage Hospitals.—Since the establishment of the first cottage hospital at Cranleigh by Mr. Napper, in 1859, the value of these institutions has been increasingly recognised, and numberless hospitals of varying sizes and of different degrees of good and bad arrangement have been established throughout the country. The Cranleigh Hospital is a very old cottage, and

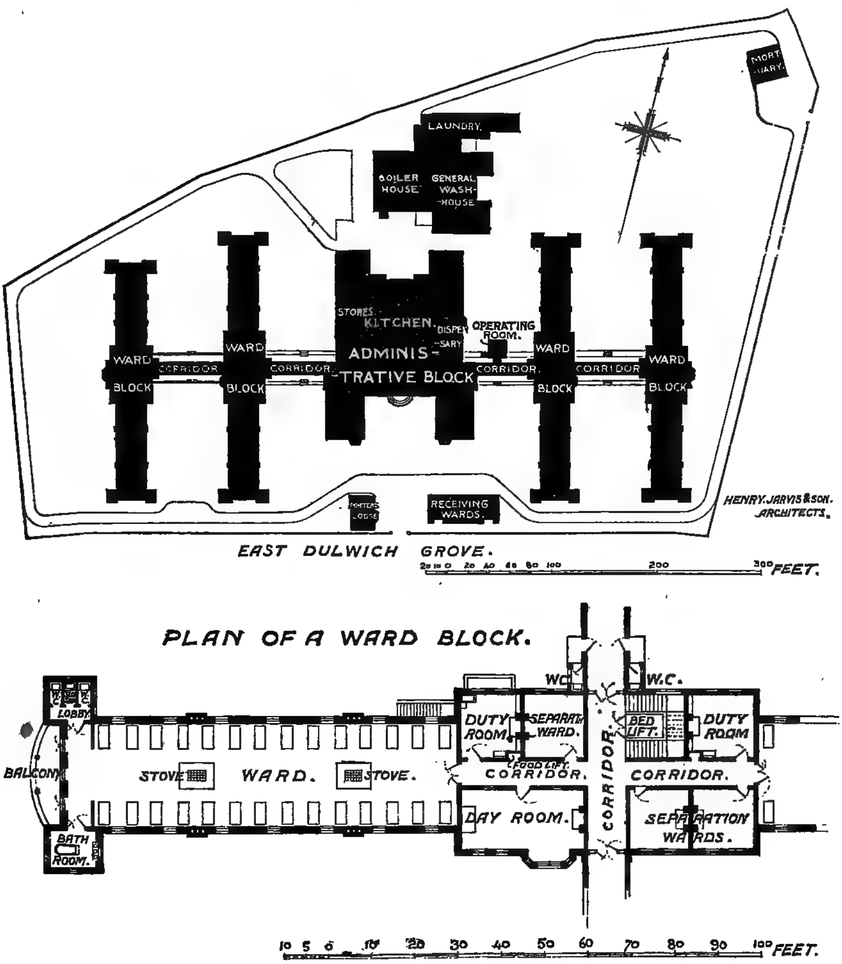


FIG. 140.—St. Saviour's Union Infirmary, Champion Hill.

the cost of its adaptation to its present purposes was only about 50*l*. Many hospitals of recent years have been built as cottage hospitals, which can in no sense of the term be called cottages. They are, in fact, small pavilion hospitals, and are planned on the lines of the larger general hospitals. A cottage hospital, then, should be, as its name implies, a building of the cottage type, with its special needs as a hospital carefully kept in view. Economy of working is an important point to be observed, as it is often difficult to obtain the funds necessary for maintaining a village hospital. The accommodation for patients in a true 'cottage' hospital will vary from four to ten or twelve, and the staff will comprise a nurse and one or two

servants. There should be a room where operations can be performed, which can also be used when required for committee meetings. The other rooms required are a sitting-room and a bedroom for the nurse, a bedroom for servants, and the usual domestic offices for a small household.

It is scarcely necessary to say that the same scrupulous attention to good sanitary arrangements are as essential in a village hospital for four beds as in a town hospital for 400, and the mistake so often made of neglecting to properly isolate the water-closets and sinks from the wards is as inexcusable in a cottage hospital as it would be in one of the largest type.

II. Special Hospitals

Not for Infectious Diseases.—In this class of hospitals are included a great number of institutions which possess no special features of interest apart from the conditions which pertain to general hospitals. Such hospitals as those for diseases of the ear and throat, cancer, and incurables require practically the same arrangements as to details and hygiene as have been described under the head of General Hospitals.

Ophthalmic hospitals require to be constructed with special reference to the condition of blindness or semi-blindness of the patients. The careful avoidance of salient angles in positions where a patient would be liable to run against them and possibly injure an eye beyond repair, and the provision of handrails on both sides of all staircases, are points that require careful attention. It is also most desirable to abolish open fireplaces in all wards and rooms used by patients, and to warm by means of hot-water pipes, with a due provision for the supply of fresh air, the flickering light of an open fire being very trying and sometimes injurious to diseased eyes. The lighting of the consulting rooms and the ventilation of the ophthalmoscope rooms are points that require careful attention. The lighting also of the operation room is important; the top light required in an operation room for a general hospital is for eye operations wholly useless. The window should be entirely vertical, and its aspect should by preference be towards the north.

Hospitals for children are practically general hospitals with a limitation to the age of the patients. Special attention must be paid to the means for isolating infectious cases, as such diseases as measles, whooping cough, and scarlatina are much more likely to arise in a children's hospital than in one for adults. The 'visiting day' is undoubtedly the chief, if not the only, cause of the evil; but inasmuch as it would be a practical impossibility to abolish 'visiting,' the only thing that can be done to minimise the evil is to provide efficient means of isolation. An isolation room must also be provided in the out-patients' department for promptly separating any child discovered to be suffering from an infectious disease.

For consumption hospitals special arrangements are necessary for the warming and ventilation, in order that, while a copious supply of fresh air is maintained, the temperature of the incoming air may be uniformly kept at such a point as will not be injurious to the lungs of the patients. Large wards are inadvisable in a hospital for chest diseases, and more day room space is also required than in a general hospital, as so large a proportion of the patients are able to leave their beds in the daytime.

Convalescent hospitals, being intended for patients who, while they have recovered from some acute illness, yet need pure air and rest to enable them to recover their strength, are more properly homes than hospitals. While they require that every detail of sanitation should be as carefully looked after as in any other hospital, there are no special features that need be further referred to here.

Lying-in hospitals, though not relatively a very numerous class, have yet suffered a notoriety beyond all others for persistent and excessive mortality. Formerly it was the custom to set apart certain wards in all general hospitals for lying-in cases, and in France this custom still exists in most of the large general hospitals. The evils which this system produced were first specially noticed in regard to the Hôtel Dieu at Paris towards the end of the last century. Later on the excessive mortality incident on parturient women at the great Maternity Hospital of Paris attracted the attention of the medical world, and in 1873–75 an enquiry conducted by M. Lefort resulted in the following facts :—

	Deaths
(1) Deliveries in general hospitals	1 in 24
(2) „ special „	1 „ 32
(3) „ at home	1 „ 528
(4) „ in houses of 'sages-femmes'	1 „ 200[1]

In London, though the lying-in hospitals are comparatively small and few in number, the record of mortality has been until recently very heavy. The largest and most important lying-in hospital in the United Kingdom is the Rotunda Hospital at Dublin; but even in this the average death-rate is stated in the report of Dr. Bristowe and Mr. Holmes as between one and two per cent., whilst the death-rate among women confined in their own homes is put by the same authorities at ·3 or even ·2 per cent. The Report of the Committee on Cubic Space in the Metropolitan Workhouses (appointed by the President of the Poor-law Board in 1866) records the remarkable fact that the mortality amongst lying-in women in workhouses was six times less than that in the largest lying-in institution in the metropolis, viz. Queen Charlotte's Hospital.

The exceptional immunity from disease enjoyed by the patients in the lying-in wards of workhouses was due in the main to the fact that separate labour rooms are commonly provided in those institutions and that each parturient woman was isolated for a time during and after delivery. And it is equally certain that the excessive mortality so persistently incident on lying-in hospitals both in this country and abroad was due to a great extent to the absence of any means of isolation.

A lying-in hospital, then, should be arranged with small rooms and not with large wards. Each patient should be kept in a separate room for a certain definite time (usually six days) after confinement, and any case of fever arising in the hospital should be promptly removed to a ward absolutely isolated from the rest of the building.

Hospitals for Infectious Diseases—In all matters that concern the question of structural hygiene the class of hospitals now to be discussed are in no degree different from other institutions of the kind. The same scrupulous attention to good ventilation, lighting, and all the various details which conduce to cleanliness and a healthy condition are equally necessary to all hospitals. But in the case of hospitals for infectious diseases there are certain points of arrangement and certain requirements which are special to the class and need to be carefully attended to.

At the outset it is needful to have a clear understanding of the purpose and objects of a hospital for infectious disease; and it may be well here to point out that, unlike the great body of general and special hospitals, most hospitals for infectious disease are public buildings provided and supported by the rates, and are in no sense charitable institutions.

[1] These figures are taken from *Hospital Construction and Management.* Mouat & Snell.

The duty of providing hospital accommodation for infectious fever has been placed by the Legislature on the various urban and rural sanitary authorities, in order that those bodies may be enabled by timely provision of suitable buildings to isolate without delay any case of an infectious fever arising within their jurisdiction. It is this point of isolation which marks the main difference between a hospital for infectious disease and one of the

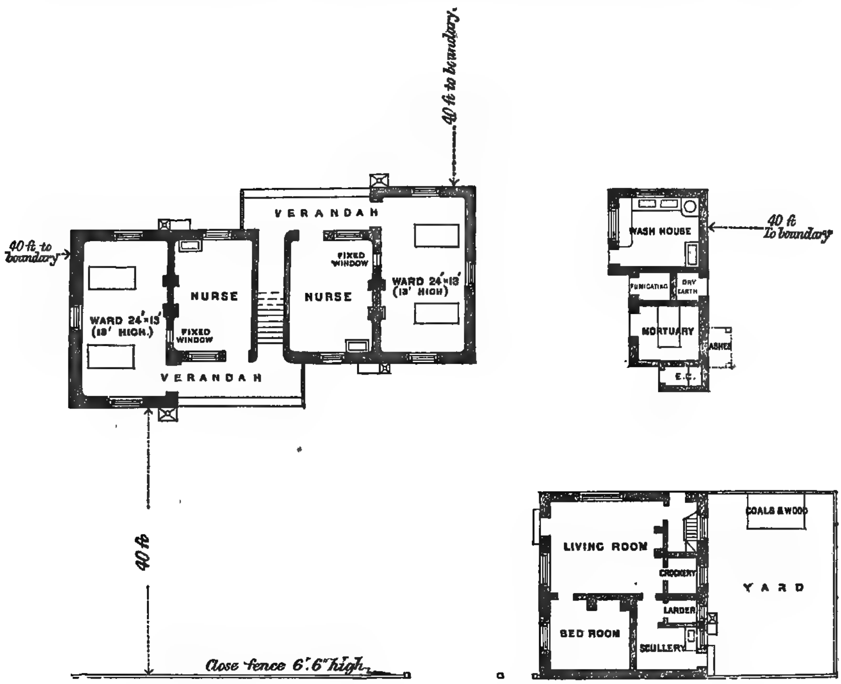


FIG. 141.

charitable class. In the former the patient is received, not primarily for his own sake, but for the sake of others, in order to prevent him from becoming a source of danger to the community. In the latter the predominant object is the good of the patient himself.

A hospital for infectious disease, therefore, is essentially a place for isolation, a means of defence against the spread of infectious disease, an important weapon with which to ward off epidemics. In order, therefore, to be of any value it is clear that the weapon must be ready to hand at any moment—must be, in fact, prepared and in working order beforehand, and not taken in hand when the disease has already made its appearance.

'It cannot be too clearly understood that an isolation hospital, to fulfil its proper purpose of sanitary defence, ought to be in readiness beforehand. During the progress of an epidemic it is of little avail to set about hospital construction. The mischief of allowing infection to spread from first cases will already have been done, and this mischief cannot be repaired. Thus, hospitals provided during an epidemic are mainly of advantage to particular patients; they have little effect in staying the further spread of infection. Moreover, hospitals provided under such circumstances, to be of any use, must be large and costly, and their construction can seldom be of a kind that is suited in after times for the isolation requirements of their districts.'[1]

[1] *Memorandum on the Provision of Isolation Hospital Accommodation by Local Sanitary Authorities*, Local Government Board, Medical Department.

Hospitals erected under pressure of an epidemic are of necessity hurriedly conceived and too hastily executed; they frequently are ready for patients only when there are no longer any patients to be received, and, as pointed out in the paragraph quoted above, they commonly prove of little or no service as permanent buildings.

The extent of hospital accommodation which it is necessary or desirable to provide must depend upon the population and other conditions peculiar to the district it has to serve. Whatever may be the amount of accommodation to be provided, however, the general principles of arrangement will remain the same.

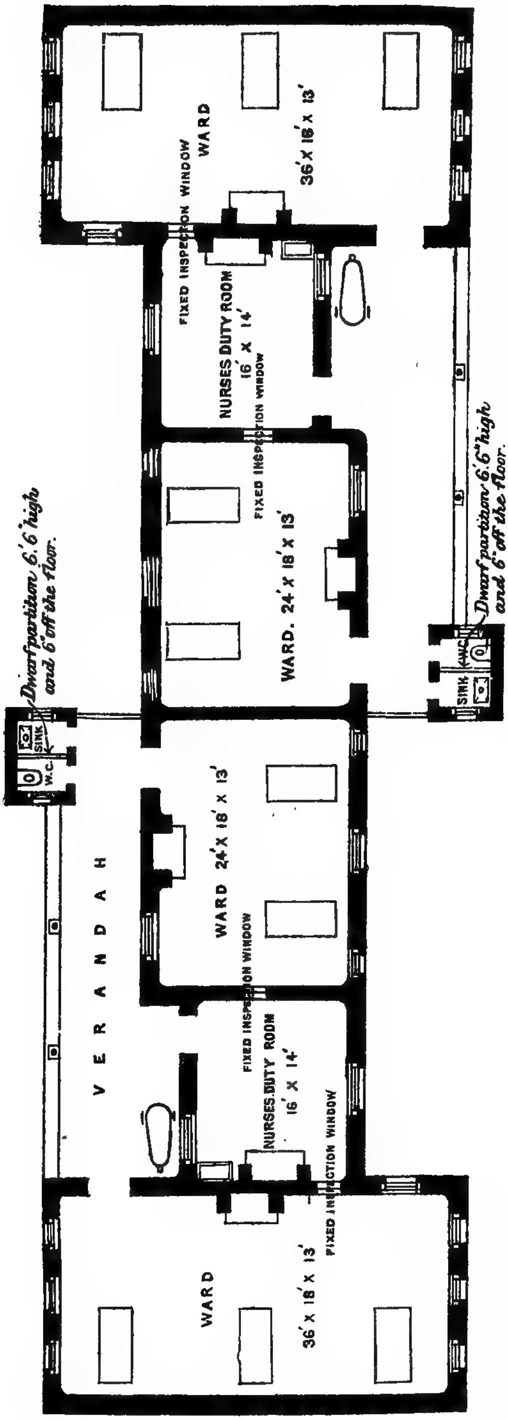
The simplest type of isolation hospital (fig. 141) must comprise three separate buildings: 1, the administration block; 2, a block for patients; and 3, the washhouse, mortuary, and disinfection house block. These three buildings may be regarded as the nucleus or irreducible minimum of an isolation hospital.

The administration block in its simplest form may comprise accommodation for a caretaker, kitchen offices, and two or three rooms for nurses; or it may be simply a cottage containing a living room and two or three bedrooms for the caretaker with the kitchen offices—such a building as that shown on the plan issued by the Local Government Board, and which accompanies the memorandum on isolation hospital accommodation quoted above.

The ward block shown on the same plan provides accommodation for two patients of each sex, with two nurses' ante-rooms on the ground floor and their bedrooms above. The third block contains a washhouse, mortuary, and a small disinfecting chamber. It will be obvious that such a hospital provides the smallest possible amount of accommodation and contemplates the reception of patients suffering from one disease only.

The next step in advance of this is to enlarge the ward block by the addition of one or more rooms for patients to each section. It then becomes the typical isolation block in which patients of each sex, and suffering from two distinct diseases, can be treated. This block is the most important one, and whatever else is omitted this must always be provided. For, take the case of a hospital consisting of a single ward block, containing two large wards with a common entrance, ward, kitchen, &c. A single patient suffering from, say, scarlatina placed in one of these wards renders the admission of patients with any other disease an impossibility. If, on the other hand, the ward block be arranged in two distinct sections as in the model plan (see fig. 142), there is always provision for at least two diseases; possibly, thanks to the verandah arrangement, for more than two.

Every hospital, then, must possess, in addition to the administration offices and the washhouse, mortuary, &c., an isolation block; and this block should always be the first consideration. The immense importance of this isolation block cannot be too strongly urged. Cases have occurred over and over again of a patient supposed to be suffering from an infectious fever being received into a hospital and placed in a ward along with other patients, the nature of whose disease was undoubted, and of the patient in question being found not to be suffering from any infectious disease whatever. This patient has then been, notwithstanding all precautions, removed, and again admitted to the same ward with the particular disease fully developed, and which had been contracted during his short previous stay in the ward. Such a case may at any time occur and will occur unless isolation hospitals are what they profess to be, and are provided with proper isolation wards into which doubtful cases can be admitted. An isolation hospital utterly fails in its purpose if it becomes the means of propagating disease to healthy persons.



PLAN OF A BLOCK FOR TEN BEDS.

FIG. 142.

In addition to this there should be a ward pavilion, or pavilions, modelled on the plan issued by the Local Government Board and containing from six to as many as twenty beds. The latter number will only occur in very large hospitals, and large hospitals for infectious diseases are not very desirable. The simplest form of the ward pavilion consists of two wards with a nurses' duty room intervening; also a linen store, small larder, and space for movable bath, and for each ward its water-closet and sink room. Such a pavilion is of course intended for patients of both sexes. In large hospitals the pavilions for each sex may with advantage be separated, and it will be of further advantage to provide one or more separation wards for one bed each in each pavilion. The space for movable bath will develop into a bathroom and should be so arranged that a patient on being discharged may step from the bathroom into the open air. A day room for convalescent patients is also a very desirable addition where it can be arranged.

The administration buildings for a large hospital will need to be on a much more extensive scale than the simple caretaker's house, with bedrooms for nurses suitable for a hospital for some twenty or thirty beds. Apartments for the matron and one or two resident medical officers will have to be provided,

also rooms for the steward and storerooms of a size proportionate to the extent of the hospital. Day rooms for nurses and servants will also be required, and ample bathing arrangements for all the staff are necessary.

The mortuary building, instead of being only a single room which has to serve the purpose both of mortuary and *post-mortem* room, will contain a properly appointed *post-mortem* room, a mortuary chamber provided with a glass screen to separate the bodies from the friends who come to see them, and a small waiting room.

The laundry, besides being increased in scale, should in large hospitals be divided into two complete laundries, one being for the patients' clothes, the other for those of the staff.

The disinfection house does not admit of great variation. In the smallest hospital, as in the largest, an efficient apparatus is a necessity, and the difference in size between the largest and smallest machine is not very great. The building containing the disinfecting apparatus must be so planned that the room in which are the articles to be disinfected is entirely shut off from all communication, except by way of the apparatus itself, with the room into which they are received after undergoing the process. This arrangement involves the necessity of having two doors to the machine, and the machine itself must pass through the dividing wall between the two rooms.

For the smaller class of hospital a single coachhouse to hold the ambulance will suffice, and indeed in many hospitals of large size room for two or three ambulances will answer all the requirements. It may, however, be desirable to arrange for a complete service, including stables and rooms for men. Such an ambulance service on a large scale has been organised by the Metropolitan Asylums Board.

Thus far reference has been made to buildings only, and it will be seen that in every detail the prevailing idea is that of isolation. In the placing of the buildings on the site and in the extent of the site itself the same idea must be constantly kept in view. It has been laid down by the Medical Department of the Local Government Board that no building which is concerned with the infected persons, such as the wards, or with infected things, such as the mortuary, laundry, ambulance house, and disinfection house, should be placed nearer than forty feet to the boundary of the site. The reasons for the adoption of forty feet as the minimum distance have been arrived at by a comparative study of the history of many hospitals with various conditions of buildings and surroundings, and experience has shown that in well-ordered hospitals with ample space about the buildings there is practically no risk of the spread of the infectious fevers, other than small-pox, beyond the walls of the hospital.

It is, however, not sufficient merely to provide a space of forty feet between the boundary and the infected buildings, but the space in question must be constituded a veritable sanitary zone to which no unauthorised person can have access. An instance of what actually occurred in a fever hospital will perhaps show more clearly than anything else the importance of this precaution. A woman whose daughter was a patient in a fever hospital went to inquire after her child, carrying in her arms her baby. On entering the hospital grounds through the gate, an ordinary five-barred one with no lock, she saw her child at the open window of one of the wards. She immediately made straight for the window, kissed the child, and held up the baby to kiss its sister, and she remained at the window talking to her child some twenty minutes before her presence was discovered. In that twenty minutes the baby had contracted scarlatina from its sister, and from that disease so caught, it died. This hospital, therefore, for lack of proper precautions and control,

became an active agent in the spread of disease, instead of being, as it should be, a safeguard and defence.

The entire site of an isolation hospital should be surrounded with a wall or fence at least high enough to prevent ingress or egress. Entrance to the hospital grounds should be by gates, which are kept under proper control, and the patients should not be allowed to enter the forty-feet space under any circumstances whatever. The importance of this latter regulation may be best illustrated by the fact that infection has actually been conveyed to persons outside a hospital by means of things thrown over the boundary fence by patients.

As illustrating the practical application of the foregoing principles the plans of two isolation hospitals are given, the first, at Warwick, being an example of the smaller type of hospital; the second, at Newcastle, being an example of a hospital suitable for a large and populous town.

The hospital at Leamington (fig. 143), erected for the Warwick Joint Hospital Board, consists at present of four detached buildings. The administration block contains rooms for the matron, nurses, and servants, and the usual kitchen offices. At one corner of the kitchen is a serving window, which opens on to a verandah, whence the meals for the patients would be handed out. The isolation block is planned on the lines of the Local Government model plan, and contains in each half a ward for three beds and two wards for one bed each, a duty room, and a water-closet or slop sink. Each half is provided with a movable bath and the hot-water supply to each is independent.

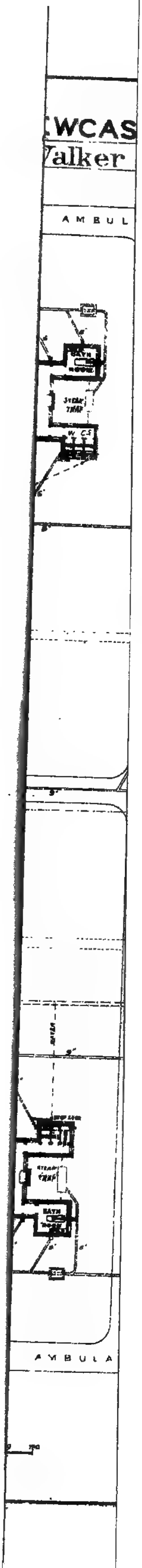
The ward block contains two wards for six beds each, with water-closet and sink, a duty room, small larder, linen closet, and a bathroom. The latter has a door leading on to the entrance porch in order that patients on being discharged may leave the bathroom direct into the open air, and so not return into the corridor after putting on their uninfected clothes.

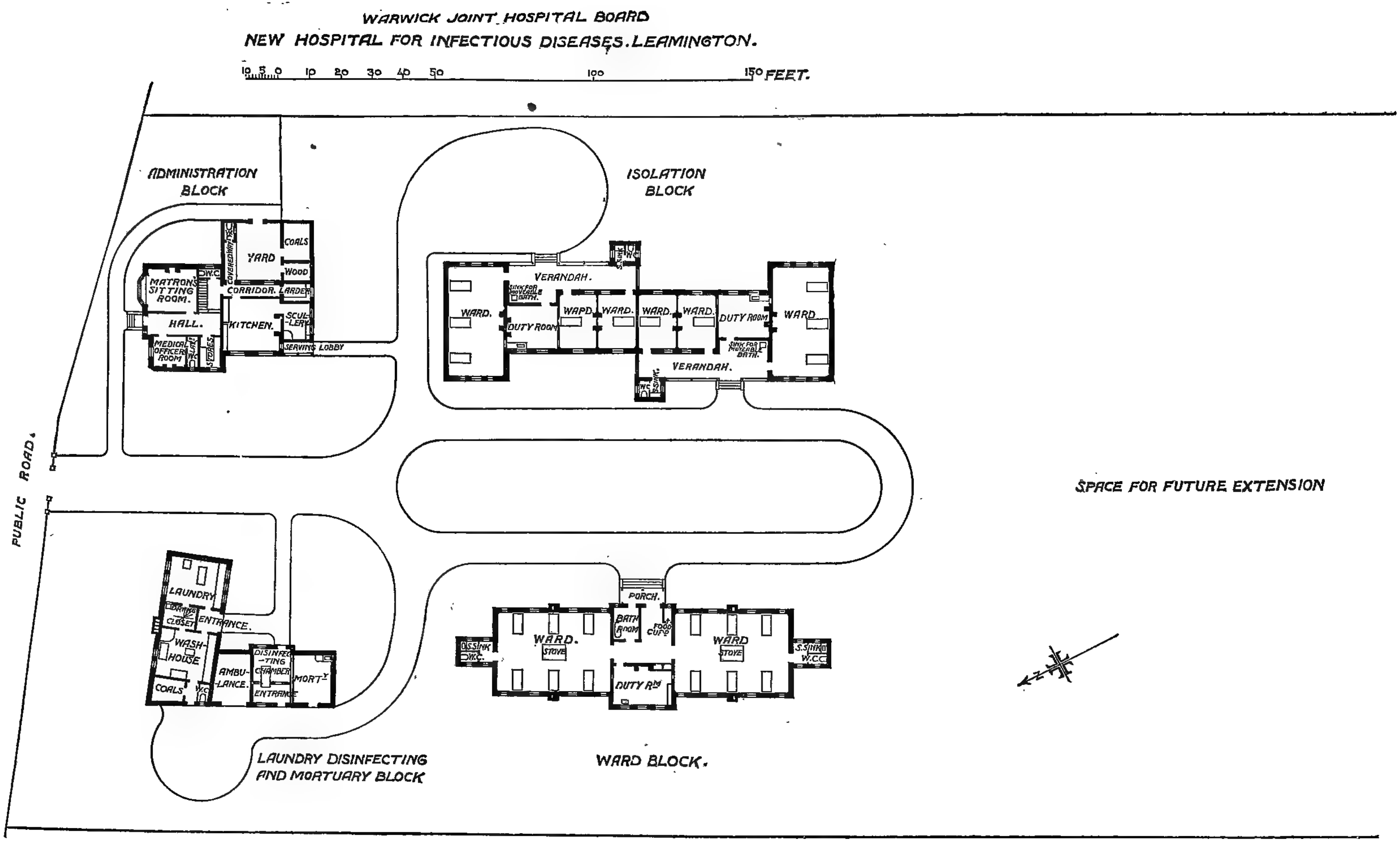
The fourth block contains the mortuary, disinfection house, ambulance house, and laundry.

The New City Hospital for Infectious Diseases at Newcastle-upon-Tyne (Plate VII.) occupies a site of about eleven acres. The buildings are eleven in number, five of them being devoted to the reception of patients. At the entrance is the porter's lodge, with carriage gates on either side, one entrance leading to the administration building, the other to the various ward blocks.

The administration block is a large building divided by a corridor into two parts, the front part containing the residence of the staff, while the back wing, which is one storey only, contains the kitchen offices, stores, and officers' laundry. The small block in the centre is an isolation block having accommodation for six patients in four wards and two duty rooms. The building is divided into two halves, whose respective entrances are on opposite sides. The four ward pavilions are each exactly alike and are arranged as follows:—

At the entrance is a receiving room, which is also used as discharging room, and is provided with means for bathing patients on their arrival and discharge; next to this is the duty room or ward scullery; on the opposite side of the passage is a covered yard, in which are placed the water-closet for nurses, coal store, and the receptacles for foul linen, dust, &c. Between the block in which the above rooms are placed and the entrance to the ward pavilion proper a cross-ventilated lobby intervenes. To the right and left of the entrance lobby are wards, each containing ten beds; immediately opposite the entrance is a nurses' room; while projecting out from the end of each ward are two small wards for one bed each. The nurses' room is provided with no less than four inspection windows, one


WCAS
Valker
AMBUL
BATH ROOM
W. CS
AMBULA



GROUND FLOOR PLAN

KEITH D. YOUNG. F.R.I.B.A. ARCHITECT.

FIG. 143.

into each large ward and one into each small ward. At the further end of each ward are two projecting wings, one containing two water-closets and a sink, the other being a bathroom.

The buildings shown in outline indicate the future extension of the hospital. The laundry and washhouse, the ambulance house and stable, the disinfection house and the mortuary are all sufficiently indicated on the plan, and present no special features calling for remark.

Besides the urban and rural sanitary authorities, to which reference has been made above, there is a third class of authority whose duties are concerned with the isolation of cases of infectious disease—port sanitary authorities. Upon these bodies falls the duty of isolating patients who are found to be suffering from any infectious fever on board vessels within their ports. Vessels arriving in port are inspected by the officers of the authority if either known or suspected of being infected.

The provision of hospital accommodation made by port sanitary authorities consists in some cases of land hospitals and in some cases of floating hospitals. As an example of the latter kind, which would appear to be the most suitable for the purpose, the following description of the floating hospital of the Tyne Port Sanitary Authority will be interesting:—

'It [the hospital] is built on ten cylindrical iron pontoons, with hemispherical ends. The buoyancy of each pontoon is 53½ tons, so that the floating power of the hospital is equal to 535 tons. The pontoons are each 70 feet long and 6 feet in diameter, and resemble huge boilers. Upon each pontoon there are seven "saddles," which support a strong framework of iron, consisting of longitudinal rolled girders. These girders are braced together by diagonal T-iron, and upon them is carried a deck of creosoted timber which constitutes a platform. Upon this deck or platform the superstructures, or the hospital and its adjuncts, are erected. It is surrounded by a neat handrail, and access from the river is obtained by a gangway in the front centre of the protection rail. The deck is partly occupied by three main buildings, six smaller structures, and a mortuary. The main buildings are each 65 feet long, 23½ feet wide, and about 20 feet high. These are divided into two hospital wards, one of which will contain six and the other four beds. They are spacious, light, and airy apartments, having large windows and special means of ventilation. The interior is lined with polished pitch pine in narrow strips. In each ward there is a central shaft through the roof, fitted with Kite's patent ventilator for carrying off the vitiated air. Near the floors there is a series of ventilators for the admission of fresh air, and under the floor of each apartment an air space of about ten inches, which will secure a constant circulation of fresh air. Beneath the surface of the river and the platform—a space of four feet—there will be a perfectly free current of pure air. The rise and fall of the tides and the current produced by the spaces between the pontoons will prevent the possibility of any impurity existing beneath the hospital. Between the two wards of each hospital is an apartment for the nurse. These apartments are fitted with glazed doors on either side, so that the nurse can command a full view of each ward. There are also entrances from the deck to the different wards. The main buildings are so arranged that they can be completely isolated, and they are all fitted up alike. The platform is 140 feet long and 80 feet wide, and there is ample space in front of the buildings for the recreation of convalescent patients. The space between the pontoons is 14½ feet from centre to centre, and each is detachable, so that any one may be removed at will for cleaning and painting. They can also be revolved in their places without removal. They are reached internally by means of

manholes, placed to correspond with trap-doors in the main or platform deck.' [1]

The treatment of small-pox in an epidemic form has of late years given rise to much discussion on account of its apparent tendency to spread beyond the walls of the hospital in a fashion entirely different from the behaviour of other infectious fevers under similar conditions.

This characteristic of small-pox was first particularly observed in 1880, when a special incidence was remarked as occurring in the immediate neighbourhood of certain of the hospitals of the Metropolitan Asylums Board in London. An inquiry into the circumstances connected with the outbreak of 1881 with reference to the Fulham Hospital resulted in the following conclusions by Mr. Power, which are characterised by Dr. Buchanan as 'unexpected but most instructive:'—

'There has been in each epidemic period an excessive incidence of small-pox on houses in the neighbourhood of the hospital as compared with more distant houses in Chelsea, Fulham, and Kensington.

'The percentage of houses invaded in the neighbourhood of the hospital has increased. This gradation has been very exact and very constant.

'Houses upon the chief lines of human intercourse with the hospital have not suffered more than houses lying in other directions from the hospitals.

'In point of time, there has been a very marked relation between the varying use of the hospital and the manifestations of excessive small-pox in the neighbourhood. This relation has not shown itself while the use of the hospital has been for convalescents only.

'The appearance of excessive small-pox in houses around the hospital has never been delayed until the hospital has become full or nearly full. It has been always most remarkable at the time when admissions to the hospital were beginning to increase rapidly.

'On comparison of different epidemics, an almost constant ratio is observed between the amount of the hospital operations and the degree of excess of small-pox in the neighbourhood.' [1]

After careful and minute inquiry into the whole administration of the hospital during the period concerned, Mr. Power was forced to the conclusion 'that there must have been some condition or conditions operating to produce the observed distribution of small-pox around the hospital that have pertained to the hospital as such, and that have been in excess of the conditions for small-pox extension as usually recognised.' [2] Other and independent observations with regard to the hospitals at Hampstead, Homerton, and Deptford, and to the old Small-pox Hospital at Highgate, produced similar results; and the whole question was inquired into by a Royal Commission.

The recommendations of the Royal Commission with regard to small-pox were that the mild and convalescent cases should be provided for in hospitals out of London, and that the acute cases, too ill to take a long land journey, should be treated in the existing hospitals, but that the number of the latter class to be received into any one hospital should be limited to thirty or forty cases.

These recommendations the Metropolitan Asylums Board met by providing at Darenth a large small-pox camp, and in the river at Long Reach a floating hospital composed of three ships, the 'Castalia,' the 'Atlas,' and

[1] *Annual Report of Medical Officer of Health to River Tyne Port Sanitary for the Year ending December* 31, 1886.

[2] *On the Use and Influence of Hospitals for Infectious Disease.* Supplement to the *Tenth Annual Report of the Local Government Board.* 1882.

the 'Endymion.' The camp is now replaced by a permanent hospital for 800 patients. The 'Castalia' and 'Atlas' are appropriated to the treatment of patients, and afford accommodation for 200 and 150 respectively, and the 'Endymion' is used for administration purposes and for housing the staff. The 'Castalia' is a twin ship built for service between Dover and Calais, for which purpose she proved to be unsuitable, and eventually came into the possession of the Metropolitan Asylums Board. Upon the upper deck are five huts, built obliquely across the long axis of the vessel. These huts form the wards of the 'upper hospital,' the 'lower hospital' being one large ward the whole width of the vessel. At each end are buildings containing the ward offices, reception rooms, bathrooms, lavatories, water-closets, and one isolation room on the lower deck and two on the upper deck. The three centre wards on the upper deck are 54 feet long by 20 feet wide; the two end ones are 50 feet long by 38 feet wide.

A laundry and other administrative buildings have been erected on the shore abreast of the ships.

To convey patients to and from the ships there is a river ambulance service, consisting of two vessels of eighty tons each and fitted up with wards for conveying patients in bed, and a smaller launch. In connection with this service there are piers with receiving rooms, waiting rooms, &c., at Blackwall, Rotherhithe, and near Wandsworth Bridge. It seems probable, therefore, that in any future epidemic of small-pox in London all or nearly all the patients will be conveyed down the river to the ships, instead of being treated in the land hospitals.

In all hospitals for infectious diseases provision must be made to prevent, if possible, the conveyance of infection to the outside world, either by patients on their discharge or by nurses or servants going outside the gates. For patients on their discharge a suite of three rooms communicating with each other should be arranged. The first room should be just sufficiently large for one patient to undress in. In this room the patient leaves his (or her) infected clothing. The second or intermediate room is a bathroom. After bathing, the patient enters the third room, where he finds a complete suit of clean, or preferably new, clothing, which he puts on. Having dressed, he should leave the building by a door leading directly into the open air, and should not again enter any part of the hospital buildings. For the staff ample bathing accommodation should be provided; in order that, as far as possible, it should be made a rule that no one employed in the hospital wards should leave the grounds without having previously bathed. It is obvious that such a rule as this cannot be rigidly enforced, but, nevertheless, the means of complying with it should be provided, and its observance should be encouraged as far as possible.

Asylums for the Insane.—Although, as a matter of fact, the great majority of patients in an asylum are persons in bodily health, the general arrangements of the buildings are not unlike those of a hospital, and the general principles of hygiene are, to a large extent, alike in both classes of buildings.

The planning of an asylum is largely governed by questions of classification, discipline, and control. The several classes of patients, usually at least four of each sex, have to be separately accommodated, workshops and laundries have to be provided for those who can work, and all have to be so placed with regard to each other and the administration offices that the labour of supervision is economised as far as is consistent with other necessary conditions.

The old system of planning an asylum was to build what practically

became one huge block, with free communication of air from one end to the other. It is now generally conceded that such a plan is hygienically bad, and that the right system is to divide the asylum into separate blocks, either of the pavilion type or some modification of the gallery ward plan, in such a manner that each section forms a separate block in itself, and is atmospherically distinct from any other block. The pavilion system obviously lends itself readily to such conditions, and with each pavilion connected to the next by a covered way, with free cross ventilation, no interchange of air from one pavilion to the other can be possible. The modified gallery ward plan has, however, advantages over the pavilion type in the internal arrangements of day rooms, and provided there is a sufficiency of cross ventilation to the dormitories, it is in some respects preferable to the pavilion system.

Whichever plan is adopted, it is of the greatest importance to arrange the day rooms in such a way that they are exposed to the direct rays of the sun to as great an extent as possible. The choice of a site, therefore, with a good south aspect is an important consideration. The site should not be too exposed, but should be protected from the north and east. 'Bleak exposed sites render the buildings much more difficult to warm, and the out-door recreation of the more feeble patients has to be greatly curtailed.' [1]

The necessity for limiting the height of the buildings to two storeys involves the covering of a large area of ground; a circumstance that cannot fail to have a favourable influence upon the health of the inmates.

The separation of the water-closets from the buildings to which they are attached by cross-ventilated lobbies is as necessary in an asylum as it is in a hospital, and the details of all such offices need to be carefully thought out, keeping always in view their liability to injury from the mischievous habits of the patients.

A liberal provision of baths must be made, and in addition to the ordinary baths it would seem to be desirable or, according to Dr. Greene,[2] necessary to provide Turkish baths also.

Every asylum must be provided with its hospital for the isolation of cases of infectious disease. The permanent accommodation need not be large, prompt isolation being the object aimed at. Some modification of the isolation block recommended for adoption by the Local Government Board would seem to meet the case admirably, in addition to which a permanent block of kitchen offices and laundry, with rooms for nurses and servants, is necessary. Should an epidemic arise, the permanent accommodation can be very readily supplemented by the erection of wooden huts or tents.

Infirmaries, Sanatoria, and Isolation Wards for Schools.—In considering the provision needful for the care and treatment of diseases arising in schools, it will be well to divide the subject into two classes: (1) the boarding schools of the higher grade, including all the large public and private schools; (2) orphanages and kindred institutions of the charitable sort and the schools of the pauper class, supported wholly or in part by contributions from the rates.

In most schools of the public school type the boarders are distributed about in various masters' houses, though in some cases the whole of them are housed in one building.

In every large school, whether it consists of boarders only or of both

[1] *The Hygiene of Asylums for the Insane.* By R. Greene, F.R.C.P.Ed., Medical Superintendent, County Asylum, Northampton.

[2] *Op. cit.*

boarders and day scholars (or 'home boarders'), suitable provision must be made: (*a*) for cases of ordinary slight ailments; (*b*) for cases of accident or severe sickness, not being infectious; and (*c*) for cases of an infectious nature.

For the first class, which would include boys sufficiently out of sorts to necessitate their staying away from school, but not in any case seriously ill, a room or two in each master's house, separated from the general dormitories, is all that is required.

The cases comprised in the two other classes require entirely separate treatment, and for them a separate building or buildings must be provided. The practice of existing schools with regard to the question of the separation of infectious from non-infectious cases is by no means uniform; but the opinion of the Medical Officers of Schools' Association on the question is very distinct. They lay down the principle that every school ought, if possible, to be provided with two buildings—an infirmary for accidents and non-infectious cases, and a sanatorium for infectious cases. No doubt this view is a sound one, and ought to be adopted wherever possible. On the other hand, the objection on the score of the additional cost of two establishments cannot be altogether disregarded, especially in the case of schools of moderate size, and the actual experience of existing schools must be allowed its due weight.

The Rugby School Sanatorium (fig. 145) is used for all kinds of illnesses, whether infectious or not, with the single exception of scarlatina, for which a separate cottage is provided in the grounds attached to the sanatorium. Here is an instance of one building serving for all purposes (with the limitation noted), and of which the medical officer says that he has never known a single instance of any disease spreading from one boy to another.[1]

The question is one of planning and of administration—planning in the sense of careful structural arrangement for absolute isolation of the various parts of the building, and administration in the sense of equally careful precautions to prevent the structural isolation being rendered useless by personal carelessness.

The proportion between the number of boarders in the school, and the accommodation to be provided for cases of sickness, will vary slightly according to the average age of the pupils. The Council of the Medical Officers of Schools' Association consider that when the average age of pupils does not exceed twelve years accommodation for 5 per cent. of the boarders is a sufficient provision of beds for non-infectious cases; but that when the average age is fifteen years the proportion of beds should be raised to 6 or 7 per cent. For cases of infectious disease the provision is fixed by the same authority at 20 per cent. if measles is to be included, and 10 per cent. excluding that disease. The total provision, therefore, may be taken at from 25 to 27 per cent., or from 15 to 17 per cent. excluding measles. These figures may be somewhat modified by the following circumstances:—

(*a*) If the school is arranged on the 'house system' and the several masters' houses are distinct and isolated, the accommodation for infectious diseases may be reduced from 20 to 16 per cent.

(*b*) If the school includes a large proportion of day scholars a further reduction of 2 per cent. may be made.

So that for infectious diseases in a school fulfilling the last-named conditions a total provision of 14 per cent. of the total number of boarders would be regarded as sufficient.

[1] Duke's *Health at School.*

Taking first the infectious class of diseases, the most important point to bear in mind is that a sanatorium (using the word as applying to the building for infectious diseases, and as distinct from the infirmary or building for non-infectious cases), is primarily a building for isolation purposes; a means, that is, of promptly separating initial cases of an infectious nature if possible before the disease has had time to communicate itself to others.

Inasmuch, however, as it is not always possible to detect and to isolate initial cases before the disease has had time to spread, provision must be made for the possible contingency of an epidemic; equally obviously a disease may be contracted by several boys at the same time and from the same cause, and thus it may happen that several cases of one disease may arise simultaneously, which yet by prompt isolation may be prevented from becoming epidemic.

Provision must also be made for the treatment of at least two infectious diseases at the same time. For, although it rarely happens that two infectious diseases are epidemic in a school at one time, yet such an occasion might arise, and it is necessary to provide against it.

The accommodation necessary to be provided in a sanatorium (assuming it to be a detached building) will comprise the following:—

1. Administration, including the matron's rooms, kitchen offices, linen and other stores, servants' rooms, and one or two spare rooms for extra nurses when required.
2. At least two general wards for from four to eight beds, eight being the maximum.
3. Two or more isolation rooms for one bed each.
4. A convalescent room.
5. Nurses' rooms, bathrooms, and small pantries adjoining the wards.
6. Water-closets for patients, for nurses, and for servants.
7. Disinfecting apparatus.
8. Ambulance house.
9. Mortuary.

The administration should be a separate block placed centrally and communicating with the ward blocks by means of corridors, either entirely open at the sides, or provided with 'through' ventilation. The matron, who should usually be a permanent officer, should have a waiting room and bedroom; and her bedroom should be placed conveniently near to either one or both the isolation rooms. As the matron will also have to act as housekeeper, the stores both of linen, crockery, and of food will have to be placed under her immediate control. A small cabinet for keeping drugs &c. under lock and key may conveniently be placed in her sitting room.

It is very desirable there should be a convalescent room, especially for scarlatina cases, with their long and tedious period of convalescence. It is not, however, an absolute necessity.

Attached to each ward must be a nurses' room, large enough to be used as a sitting room by day and bedroom by night. It should be entered from the corridor and may, if desired, have a small window overlooking the ward, though there is little practical utility in the latter arrangement. For each ward must also be provided a small pantry or duty room, sufficiently large to contain a sink, china cupboard, and a small gas stove for warming beef-tea and preparing special invalid food, drinks, &c. Adjoining the last should be the bathroom, so arranged that a patient can on his discharge leave the sanatorium by the casement window instead of going back into the corridor. The water-closets for the patients should of course be placed in projecting wings, with a cross-ventilated lobby interposed between them and the wards.

One water-closet must be provided for the nursing staff and one for the servants, and these also should be cut off by cross-ventilated lobbies, though the latter might be out of doors in a small yard. Where possible a bathroom should be provided for the nurses in order that they may have a bath and a complete change of clothes before going outside the sanatorium.

A properly arranged disinfection apparatus is a necessity of the highest importance. The building in which it is placed should be divided into two rooms by a brick wall, and the apparatus provided with two doors fitted so

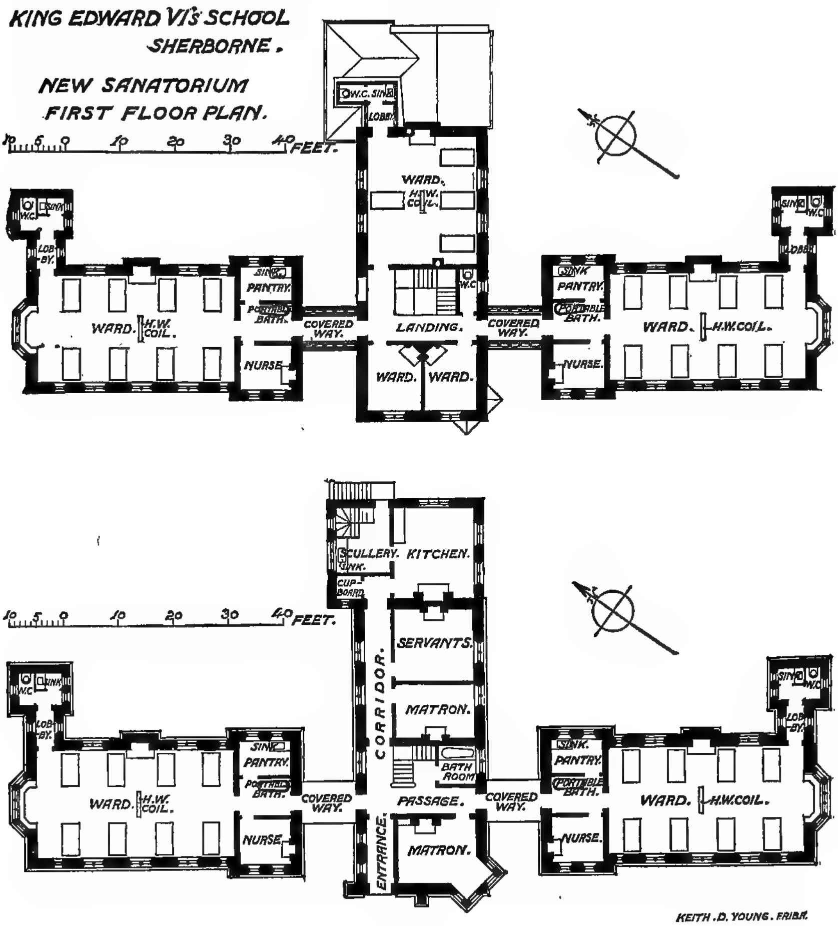


FIG. 144.

that one door of it opens into one room and the other door into the other room. Clothing to be disinfected will be taken into one room, which will be devoted solely to the reception of infected things, placed in the apparatus, and when disinfected taken out at the door in the other room, into which latter, therefore, only disinfected clothes will come. The apparatus should be supplied with suitable means of drying the clothes if these are exposed to the application of steam.

An ambulance house will be required where patients have to be brought from or sent away to any great distance.

A small detached chamber suitably constructed must be set apart for the temporary reception of the body of any patient dying in the sanatorium.

The sanatorium erected in 1887 for King Edward VI.'s School at Sherborne is an example of a building intended for the treatment of infectious diseases only. It consists, as will be seen from the plan (fig. 144), of two distinct blocks connected to each other by covered ways entirely open at the sides.

The centre block contains on the ground floor the matron's sitting room and bedroom, servants' bedroom, and kitchen offices. Advantage is taken of the fall of the ground eastwards to get an additional floor under the kitchen, in which are placed the larder, coal store, boiler room, and servants' water-closet.

On the upper floor of this block are two isolation wards for one bed each, having a floor area of 117 feet and cubic space of 1,525 feet; and a ward for four beds, with a floor area of 118 feet and cubic space of 1,522 feet per bed.

The south-east block contains on each floor a small pantry, with space outside for a portable bath, a nurses' room, and a general ward for eight beds, with water-closet and sink room attached. Each ward has a floor area of 90 feet and cubic space of 1,080 feet per bed; in addition to which is a bay window of sufficient size to hold a table at which convalescent boys can have their meals. Each ward is warmed by two hot-water coils in addition to a large open fireplace.

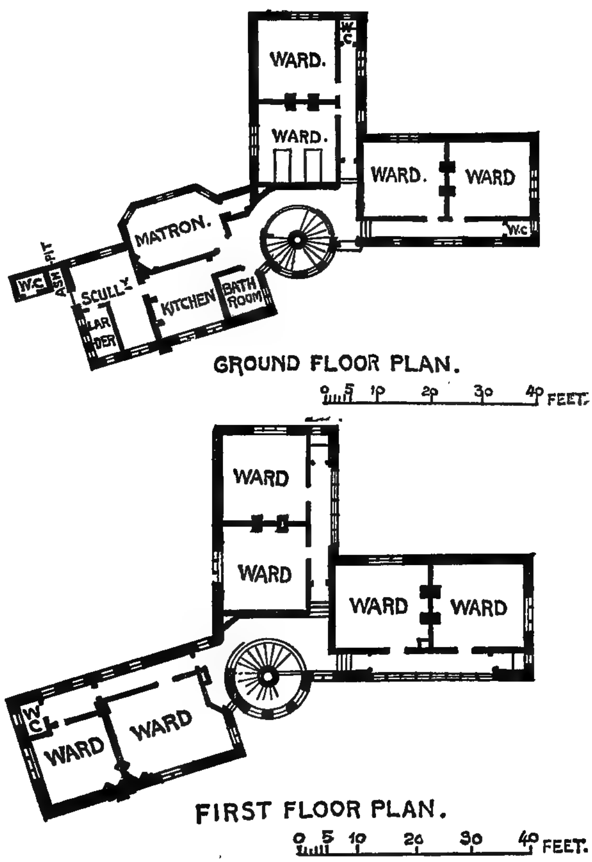


Fig. 145.—Rugby School Infirmary.

The central block and the south-east wing only have at present been erected, the remaining wing being left for future erection.

As an example of an infirmary for both infectious and non-infectious cases, we are enabled, through the courtesy of the head master (Dr. Percival) and the architect (Mr. F. C. Penrose), to reproduce the plan of the Rugby School Infirmary, built in the year 1859.[1] (Fig. 145.)

This building consists of three wings, radiating from a central circular

[1] The plan here given is reproduced, with the author's permission, from Dr. Duke's *Health at School.*

staircase. On the ground floor two of the wings are devoted to sick-rooms, and the third to the administration, matron's quarters, kitchen offices, and bathroom. The upper floor contains five sick-rooms and the matron's bedroom. All diseases, with the exception of scarlatina, for which a separate cottage is provided, are treated in this building, and the medical officer considers that the arrangement of the building lends itself admirably to the purpose.

The sick-rooms give a floor space of 116 feet and cubic space of 1,320 feet per bed, allowing two beds to each room.

Hitherto reference has been made chiefly to schools of the larger kind, but it is equally essential, even in the smallest kind of school, as, for instance, a private boarding school of only twenty or thirty pupils, to provide adequate means of isolating a case of real or suspected infectious disease. This can sometimes be done by setting apart a room or two on the top floor of the building, or in a projecting wing, and contriving a separate staircase approached only from the outside. Two rooms are, of course, better than one, and a separate water-closet, and if possible a bathroom, ought also to be arranged. This arrangement must, however, be regarded at best as but a makeshift.

Hospital provision is also required for children of the pauper class, separate from the workhouses, such as those which belong to metropolitan and certain large provincial Poor-law unions. For schools of this class provision has to be made: (*a*) for the isolation or quarantine of children on their admission to the school, in order to prevent the introduction of any cases of contagious disease into the general body of the school; these are usually called probation wards; (*b*) for sick-wards for cases of ordinary non-infectious ailments; and (*c*) for isolation wards for cases of infectious disease. The probation wards should be more in the nature of an 'observation school,' so to speak, than an infirmary; for the children in them will be to a large extent well and perfectly able to continue their education. It has been suggested that, instead of each school being provided with its own probation wards, a separate probation school should be made to serve for a group of several schools, 'where sickly children, and children admitted in a state of actual disease, should be kept for an indefinite time.'[1]

The infirmary for ordinary sickness of a non-infectious nature should be a separate building, removed from the noise and bustle of class-rooms and playground, and amply provided with means of classifying the various diseases. Such diseases as ringworm and other contagious disorders should be provided for here, carefully separated from all other diseases.

The isolation hospital for infectious diseases should provide means of treating simultaneously at least two different infectious diseases. It should be constructed in the same way as an ordinary fever hospital, and there should be sufficient ground attached both for exercise for the convalescent patients and for providing temporary increased accommodation by putting up tents or huts to meet the demands of an epidemic.

The most serious difficulty, however, with which the managers of these large schools have to cope is the spread of ophthalmia. This disease, which is one to which children of the pauper class are, for various reasons, excessively prone, is liable to spread from child to child in the most rapid fashion. To prevent the introduction of ophthalmia into a school from outside is one of the chief functions of the probation wards; and it was mainly with a view

[1] *Report on Ophthalmia in the Metropolitan Pauper School.* By E. Nettleship, F.R.C.S.

to the elimination of this disease that the suggestion referred to above was made.

Ophthalmia is, however, largely produced by the conditions under which these large schools are carried on. And that this is the most important part of the subject is proved by the fact that, according to the authority before cited, 'the risk of getting ophthalmia is very far greater in the metropolitan pauper schools than outside them.'[1] It may, and in fact in one of the large metropolitan schools it quite recently has become necessary to provide for the accommodation of a large number of children suffering from ophthalmia. In the case referred to, the buildings are of a temporary nature; but it would probably be better to contemplate such a possibility as a large outbreak of the disease when arranging the plan of a large school, and to provide at any rate a permanent nucleus to be increased when necessity arises by additions of a more temporary nature.

Ventilation and Warming of Hospitals

Though, relatively, good ventilation is of more paramount importance in a hospital ward than the mode of warming, the two are so intimately connected, and in some cases so independent, that it is undesirable, if not impracticable, to treat the one to the exclusion of the other. The object of ventilation is to secure to each patient a constant supply of pure air, or air of such purity as is attainable, in such a ratio that the air which he inhales shall not be polluted beyond a given standard, either by his own or other people's exhalations. It has been found in practice that every adult requires a supply of 3,000 cubic feet of fresh air per hour in order that the total impurity of the air may not exceed 0·6 per 1,000. In a hospital ward, therefore, with a cubic space of 1,000 feet per bed the air must be completely changed three times in every hour; at which rate, if the means of ventilation provide for steady and gradual movement of air, the change will be effected without causing draught. In certain wards, as those for fever and for acute surgical cases, at least double this amount of air is necessary. The means adopted to provide this necessary movement of air are commonly divided into two classes—(1) natural and (2) artificial or mechanical ventilation.

In the first class, or what is commonly known as natural ventilation, the agency of windows, simple shafts through the walls, and the extracting power of open fireplaces is relied upon to produce the required effect. The particular form of windows best suited to hospital requirements and their positions in relation to each other is discussed elsewhere. Air may also be admitted by so-called 'Tobin' tubes, which are simply vertical tubes connected at their lower ends with the open air, and with their upper ends opening into the ward, and the object of which is to admit air in a vertical direction; air-shafts through the wall at the floor level, either with or without movable shutters for closing; or by similar shafts at the ceiling level. Openings into the smoke flues or extraction shafts provided with flap valves to prevent down draught are of course only useful as outlets for vitiated air. The openings at the floor level should be placed behind the beds, and are intended to effect a circulation of air at a part of the ward most liable to stagnation. The openings at the ceiling level are accessory inlets to the windows, and are frequently fixed permanently open. If properly protected with 'hoppers,' they provide valuable means of ventilation when the windows are shut.

[1] Nettleship, *op. cit.*

The special form of open fireplace most suitable for a ward need not here be discussed in detail; it will be sufficient to point out that a stove which is provided with a supply of fresh air from without is preferable to one which depends entirely upon the ward for its air for combustion. It is customary in English hospitals to have fires burning in the wards all the year round, and there is no doubt that the practice is very helpful to efficient ventilation.

Artificial ventilation may be roughly divided into two classes: (1) ventilation by extraction and (2) ventilation by propulsion. Strictly speaking, the action of the chimney flue of an open fire is ventilation by extraction, inasmuch as the extractive power of the flue depends on the expansion of the heated column of air inside it. The two systems exist side by side at the Lariboisière Hospital, Paris, where one-half of the hospital is ventilated by a system of propulsion, and the other by a system of extraction. In the former system air is forced into the wards by means of a fan worked by a steam engine, and is warmed by passing over steam pipes before entering the wards. The vitiated air is by this system driven out through the outlet shafts by the force of the entering stream of pure air. In the system of ventilation by extraction the motive power is placed in a main extraction-shaft, into which the various subordinate flues join, the power being a hot-water stove, which by heating the air in the shaft causes it to expand, and so draws the air from the wards through the various shafts. The fresh air enters of its own accord to supply the place of the air drawn off into the outlet shafts. In this system the warming is accomplished by means of hot water.

One of the most recent and probably most perfect systems of ventilation applied to hospital wards is that adopted at the Johns Hopkins Hospital, Baltimore. The wards here are contained in detached pavilions of one storey and a basement. 'The basement is devoted entirely to heating and ventilating purposes, forming practically a large clean-air chamber containing the hot-water coils for heating, and from which the air supply for these coils can be taken when desired. Usually, however, the supply will be taken directly from the external air. . . . Each of the wards has a separate aspirating chimney, located in an octagonal hall or vestibule on the connecting corridor. Into this chimney empties a foul-air duct, which runs longitudinally beneath the centre of the floor of the ward, and which receives the air from lateral ducts opening beneath the foot of each bed. The main foul-air trunk is of wood, lined with galvanised iron, and the lateral pipes are of galvanised iron and cylindrical in shape. A similar duct is placed above the ceiling and communicates with the ward by five openings in the ceiling in the longitudinal central axis. Just above where this upper duct enters the chimney there is placed in the shaft a coil to be heated by high-pressure steam when it is necessary to quicken the aspirating movement.'[1] It will be seen from the foregoing description that the system adopted is one of extraction. The position of the extraction outlets in the wards can be varied; the air can be taken out either at the floor level beneath the beds or from the centre of the ceiling; and it is intended to employ the former method in the winter, and the latter in the summer. In the basement is placed a small propelling fan connected with the heating coils, the function of which is to secure a thorough air flush of the ward two or three times a day, and also to supplement the aspirating shaft when occasion requires. This plan combines, therefore, the two methods of propulsion and aspiration, though the ordinary method of working is by aspiration only.

In most hospitals on the Continent mechanical means of ventilating the

[1] *Ventilation and Heating.* By John S. Billings, M.D., Surgeon-General, U.S. Army.

wards are employed. The system adopted at the Lariboisière has been described above, and may be taken as a fair example of French methods. In Germany the use of 'calorifères' is largely adopted; these are large hot-air stoves usually, as at Dresden, the furnaces of which are situated in the basement below the wards. The upper part of the 'calorifère' is in the ward, and is generally cased with porcelain tile. The fresh air is admitted in the basement warmed by the furnace and ascends into the wards through the tile-incased upper portion. In the summer the fresh air is frequently made to pass over running water or ice on its way to the wards. In several of the newer hospitals in Germany and France the ventilating appliances are much simplified. At Halle, for instance, the windows and ventilating openings in the roof are relied upon entirely; while for the winter, when the cold is too great to allow of the use of open windows, an arrangement is made by which the vitiated air can be extracted through an underground flue, communicating with the furnace shaft of the boiler house. The supply of fresh air is warmed before it enters the wards by passing over hot-water pipes.

The question of the relative value of natural as compared with artificial ventilation is largely if not entirely a question of climate. Both on the Continent and in America, it is considered that the very large variations of temperature which occur demand the employment of mechanical aids to ventilation. In America particularly the need for artificial ventilation is much insisted on, not only for hospitals and other public institutions, but also for dwelling houses. Owing to the very great variations of temperature, and to the extreme dryness of the air, especially in the northern parts of the United States, it is necessary that a temperature of from 68° to 70° F. should be kept up in dwelling rooms. In this country, on the other hand, the variations of temperature are very much less, and the relative humidity of the air permits of a much lower temperature being kept up. It may, indeed, be safely affirmed that there are very few days in the average year when the weather is so cold as to compel the closing of the windows in a hospital ward. It is therefore generally agreed that the simpler methods are the most suitable for hospital purposes in this country.

There is, however, one purpose for which some well-devised system of mechanical ventilation would seem to be desirable—that is for the wards of small-pox hospitals. But the end to be aimed at is not only the ventilation of the wards, but the complete destruction of all the air that is discharged from the wards. The idea was first suggested by Dr. Burdon Sanderson, F.R.S., in his evidence before the Royal Commission on Small-pox and Fever Hospitals, of which he was a member. The plan proposed by Dr. Sanderson consisted of an annular ward, with a central circular shaft for the extraction of foul air. The beds were placed around the inner wall instead of against the outer wall, as is usual in circular wards, and at the back of each bed was placed an extraction opening. The windows were fixtures, and openings for the admission of fresh air, having two square feet of area each, were placed in the outer wall. The extracting power was to be a fan propelled by steam, and the air supply per patient 10,000 feet, moving at the rate of one mile per hour. The air extracted by the fan was to be passed through a furnace of which the heat should be supplied by gas. Upon this scheme Dr. Billings commented thus. After pointing out that the beds would be more conveniently placed if arranged against the outer wall, he says:—'A second objection is that the central shaft is unnecessarily large, as are also the inlets into it. It is not desirable to reduce the velocity of the air at the outlets or in foul-air ducts below four or five feet per second, because at very low velocities a very slight thing will disturb the currents. The velocity at

the outlets has comparatively little to do with the production of draughts. There seems to be no necessity whatever for the use of an aspirating fan in the plan proposed. If the air is to be heated to a temperature of 250° F. and upward, which is necessary to secure its disinfection, this heat will in itself furnish all the aspirating power required. The use of gas to produce the heat required for such large quantities of air would also be unnecessarily expensive; a coal furnace would do the same work at half the cost.'[1] Notwithstanding these and some other shortcomings on points of detail touched upon by Dr. Billings, the plan is valuable for its suggestiveness. That such a mode of dealing with the infected air of a small-pox ward is practicable there can be no doubt; the question of the best mode of carrying it out is one of detail and of by no means insuperable difficulty.

DRAINAGE OF THE DWELLING

In this section will be included the drainage arrangements and the fittings in connection therewith, up to the point where the liquid refuse from the house is discharged either into the sewer, cesspool, or system of irrigation; in other words, it will treat of the conveyance of sewage out of the premises, but not of its ultimate disposal either by sewers, cesspools, or on to the land. It will also concern itself exclusively with water-borne systems of drainage, and not with any form of dry system.

The function of a drain is to convey to its destination with as much dispatch as possible all the refuse or waste matter from a house that can properly be carried away by the agency of water. To accomplish this object aright, the drain should be made of such materials and of such a form as to render it impossible for its contents to leak out, or for them to accumulate inside. In its form, therefore, in the nature of the material of which it is made, and in the mode of laying, a drain must throughout its entire course be such as to offer the least possible obstacle to the rapid progress of its contents towards their destination; it must also be impervious both as to the material of which it is made, and as to the joints between its different sections. Further, it is necessary that the air in the drain should not be allowed to escape therefrom except at such exits as may be provided for that purpose. A drain must therefore be both air- and water-tight.

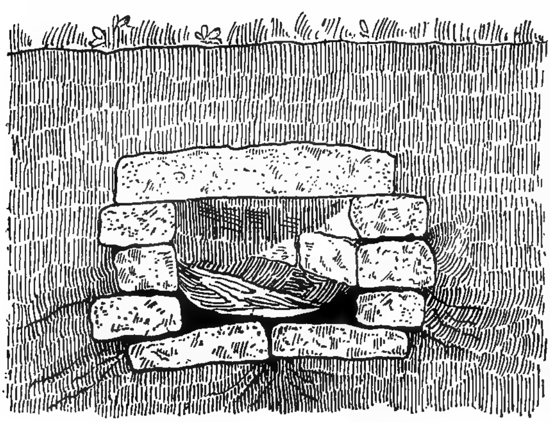


FIG. 146.

Formerly drains were commonly made of brick or of slabs of stone, and were square in section. Drains of this kind are still to be found in many places; the example shown in fig. 146 was sketched in 1887 in a Surrey village and in all probability exists to this day. The defects of such a form of drain are obvious. In the first place the form

[1] *Ventilation and Heating*, *op. cit.* p. 178.

itself is, of all forms, the one least adapted for facilitating the flow of water along it. Secondly, a drain so constructed allows the contents to pass readily through its sides into the surrounding earth. Brick drains with a circular section are an improvement upon the square form, and may still be found occasionally so well made and of such good materials as to be practically impervious, but they are usually much larger than necessary or desirable. Drains of this kind are, however, unsuitable for house drainage, inasmuch as the surface, however well they may be constructed, is comparatively rough, and the material is liable to be affected by time and constant action of running water. The brick drain commonly used before the introduction of glazed pipes was, as a rule, made of ordinary bricks put together with mortar. The action of the water and detritus carried with it on the soft bricks and the mortar joints, aided by the operations of rats, soon reduced these drains to something like the condition of a sponge; and whenever a drain of this kind is removed, as they frequently are, from old houses in London and elsewhere, the surrounding earth is found to be saturated with sewage that has leaked out through the brickwork of the drain itself (fig. 146).

The form of drain now most generally used is a circular pipe made in lengths of about two feet of stoneware glazed with a salt glaze and provided at one end of each length with a socket into which the other or spigot end of the next pipe fits. Between the spigot end of one pipe and the surrounding socket of the next is an annular space, which is filled with some material intended to make the joint watertight. The material in common use for this purpose some twenty years ago, and still extensively used, is puddled clay, because where the pipes are carelessly laid on a defective foundation, subsidences and settlements are certain to occur, and the clay would give with the altered position of the pipes; whereas if a harder material, such as cement, were used for jointing these defectively laid pipes, breakages would be likely to occur in the pipes, sockets, or joint. The clay, however, in the course of a comparatively short time, will inevitably be washed out of the joints, and for all the protection it affords might just as well have been omitted and the pipes laid with open joints. Portland cement, if carefully applied, makes an excellent and lasting joint; but care needs to be taken to ensure that any cement that squeezes out of the joint into the interior of the pipe is entirely wiped off, or it will 'set' and leave ridges inside that will form so many obstructions to the flow of water, and lodging places for solid matters carried down with the sewage. It is needful also to be certain that the cement is properly applied all round the joint, as careless or dishonest workmen will often make a neat joint so far as it is visible on the top of the pipes, while leaving the underside entirely devoid of cement. Another kind of joint, which has been much used of late years, is made by casting on to the spigot and socket of each pipe a ring of specially prepared patent material, the two rings being fixed *in situ* with a composition of Russian tallow and resin. This joint will bear testing with water within a very much shorter time after its completion than is the case with cement; and there is, moreover, nothing to squeeze up inside the pipe after the joint is made. It is, however, desirable to make sure of its durability by adding a ring of cement outside the patent joint.

Of not less importance than a watertight joint is a firm and solid foundation on which to rest the pipe. If a drain be laid in a soft and yielding bed, subsidence will inevitably take place, with the result that the joints, if of cement, will be broken, and the drain will cease to be watertight, while the gradient will be rendered irregular and deposits of sewage will occur in the drains.

If, therefore, the soil upon which a drain has to be laid is not of sufficient solidity and compactness as to render all chance of subsidence impossible, the pipes must be laid on a bed of concrete of such thickness as the nature of the case demands, but never less than three inches under the centre of the pipes. When the pipes have been laid and tested the concrete should be filled in around them up to the line of the horizontal diameter (see fig. 147).

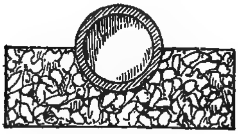


FIG. 147.

The fall or inclination to be given to a drain is a point upon which no definite rules can be laid down, as the possible fall will always depend upon the circumstances peculiar to each case. It must, however, be premised that the fall should be a regular one, and not, as is too often found to be the case in carelessly executed work, that one pipe should have a fall of some two or three inches, the next be laid quite flat, and the next falling perchance the reverse way. Having found the level of the starting point of the drain, and the level of the outfall, the pipes should be laid with an even fall from point to point. What the fall is to be must, as has been said, depend upon circumstances; but it may be taken as a general rule that a house drain should have a fall of at least 1 in 50. When the fall obtainable is less than this, the scouring or cleansing of the drains cannot be effectually accomplished without the aid of special flushing, of which further mention will be made hereafter.

The following table[1] of the discharge per minute of various sizes of drains when running full will be found useful:—

Diameter of pipe	Velocity 3 feet per second		Velocity 4½ feet per second		Velocity 6 feet per second		Velocity 9 feet per second	
	Fall	Discharge per minute	Fall	Discharge per minute	Fall	Discharge per minute	Fall	Discharge per minute
Inches		Gallons		Gallons		Gallons		Gallons
3	1 in 69	54	1 in 30·4	81·0	1 in 17·2	108	1 in 7·6	162
4	1 in 92	96	1 in 40·8	144·0	1 in 23·0	192	1 in 10·2	288
6	1 in 138	216	1 in 61·2	32 ·0	1 in 34·5	432	1 in 15·3	648
9	1 in 207	495	1 in 92·0	742·5	1 in 51·7	990	1 in 23·0	1,485
12	1 in 276	876	1 in 122·4	1314·0	1 in 69·0	1752	1 in 30·6	2,628

The size of pipes to be employed is also a matter which must depend on circumstances. As a rule, house drains are frequently laid with pipes of much too large diameter; and unfortunately many local authorities are apt to insist upon the use of the larger pipes, on the plea that the smaller ones are more readily choked. If drains are always to be laid in the old careless and haphazard way, there is some justification in the argument; but as the object of good drainage is to render the occurrence of a stoppage impossible, there is no need to unduly increase the area of pipe surface which has to be flushed and the capacity which has to be ventilated. Drain pipes are made usually in three sizes—of 4 in., 6 in., and 9 in. diameter. The area of a 4-in. pipe is 12·56 inches, while that of a 6-in. pipe is 28·27 inches, or considerably more than double that of a 4-in. pipe; while a 9-in. pipe has a sectional area of 63·61 inches. The same amount of water, therefore, that would fill a 4-in.

[1] From *A Handbook of House Sanitation*. By E. F. Bailey-Denton, C.E., B.A. London, 1882.

pipe would not nearly half fill a 6-in. pipe; consequently the flushing power of the same volume of water is proportionately reduced. As a general rule, a 4-in. pipe is sufficient for the drainage of moderate-sized houses, a 6-in. will suffice for a large mansion, while 9-in. pipes are only needed for the main and outfall drains of large institutions.

No drains ought to be laid under houses when it is possible to lay them outside. In some instances, however, as in houses in terraces or streets of towns, the drains must pass under the house in order to reach the sewer. In such cases extra precautions are necessary to prevent the leakage of air or water into the soil under the house. A good plan is to use iron instead of stoneware pipes, one advantage of which is that there are fewer joints to make, the pipes being cast in 10 or 12 feet lengths instead of 2 feet; and the joints can be securely caulked with lead. In any case the pipes, whether they be of stoneware or of iron, should be completely encased in concrete.

The paramount necessity for the greatest accuracy in laying out a system of drainage can hardly be too strongly insisted upon. Absolute precision not only in designing the scheme, but in carrying it out to its smallest details,

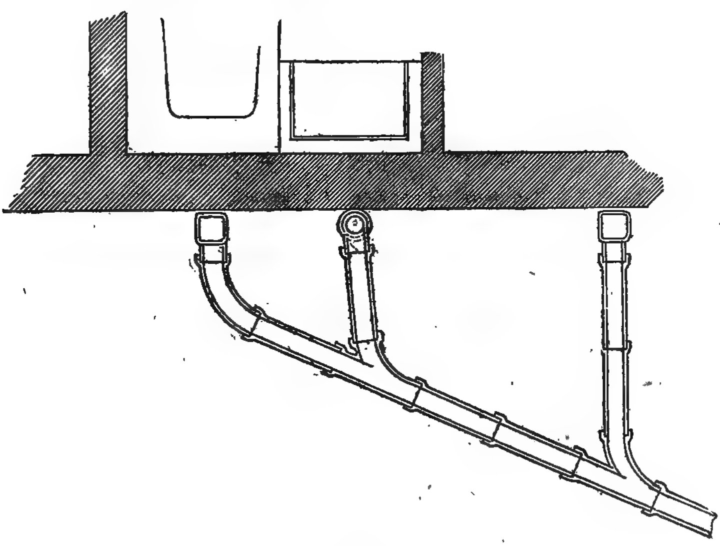


FIG. 148.

is as important in the drainage of a house as it is in the sewerage of a town. Unfortunately, however, while the highest engineering skill is brought to bear on the wholesale disposal of the sewage of a large community, the details of drainage to individual houses are too often entrusted to the unskilled hand of a builder's foreman.

The plan upon which the drains of a house are laid is also a matter which requires careful consideration. Provision should be made for ready inspection of every part of the drains, without its being necessary to dig out the ground or tear up floors. This can only be done effectually if the drains are laid out in straight lines from point to point, and if, at each change of direction or junction between two or more pipes, an access chamber or manhole is built. The old-fashioned plan of laying drains in all sorts of directions, using curved lines by preference where straight lines would have better accomplished the purpose, is now very generally abandoned. Examples of good and bad plans of drainage are given at figs. 148 and 149. An access

chamber or manhole is formed by building a square pit of sufficient size to permit of a man getting down into it to examine the drain. At the bottom of the pit the main drain runs through in a glazed channel or half-pipe, and the branch pipes all deliver either on to the main channel or at the same level, and are formed of similar half-pipes curved on plan (figs. 150 and 151).

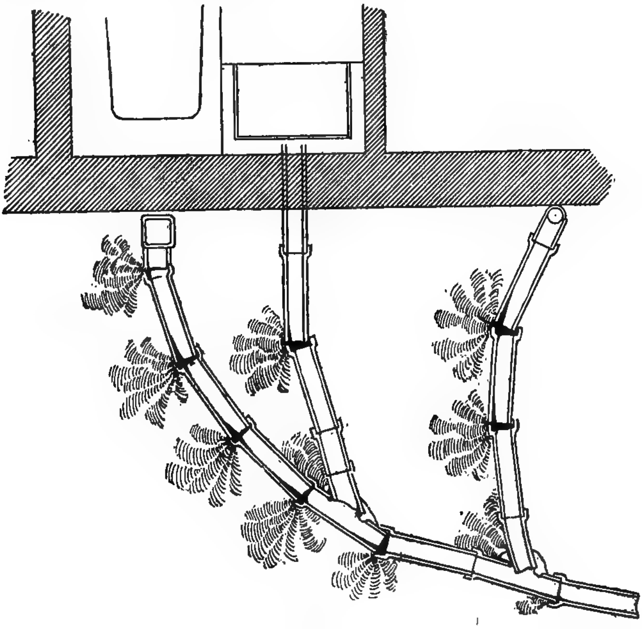


FIG. 149.

The top of the manhole is covered with a hinged iron lid, which should have an air-tight joint (fig. 151).

With such a system of drainage, having practically free access to every part, the application of any test desired is rendered very simple.

All drains should be tested when complete in order to ascertain if they

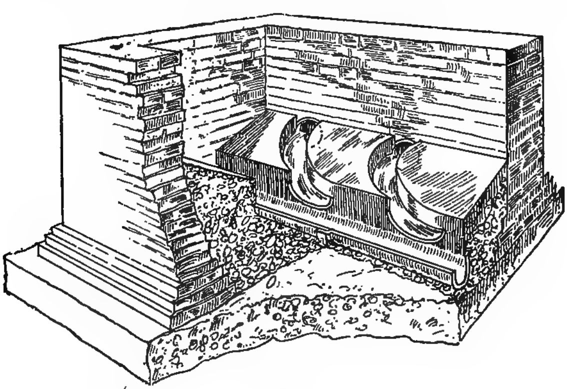


FIG. 150.

fulfil the required conditions of soundness. This is most effectually done by plugging the lower end, and filling the pipes with water, which should be allowed to stand for such a time as experience will suggest before the drain is passed as complete and perfect. The water test is a very severe one,

especially in long lengths of drains and where the fall is great, and will infallibly detect any faulty places either in pipes or in joints. Pipes can now be had which have been submitted to hydraulic pressure and which are marked 'tested;' a great advantage to the builder, as the makers undertake to replace any pipes which prove defective under test when laid and jointed.

Traps are appliances used for the purpose of keeping back the sewer air from the drains or the drain-air from the house or its surrounding air; and the method by which the air is kept back is by the interposition of a body of water, called a 'water seal,' between the inlet to, and the outlet from, the trap.

A form of trap which was almost universally used in former times, and is at times met with now, is what is known as a 'mason's' or 'dip' trap. It consists (fig. 152) of a square chamber divided across the middle by a vertical slab of stone which extends up to the top but stops short of the bottom sufficiently to allow the sewage to pass from the first into the second division. These dip traps are often found with a very considerable space between the bottom of the dip-stone and the floor of the chamber; the result of which

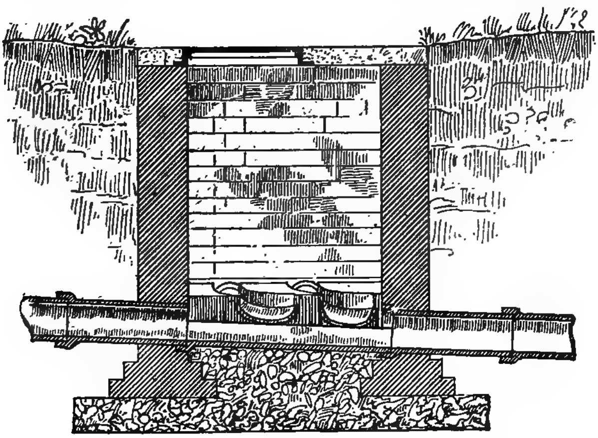


FIG. 151.

arrangement is a very considerable accumulation of solid refuse on the floor. At best this form of trap is a most defective one, and becomes a small cess-pool, or storage tank, for decomposing organic matter.

The only suitable kind of trap to be used for cutting off the house drain from the sewer or cesspool is what is known as a 'siphon' trap. It is in reality not a siphon at all, but a pipe bent in such a way that there is always a water seal between the inlet and the outlet. There are several forms of trap suitable for the purpose; the one shown in fig. 153 was devised by Mr. Rogers Field, C.E., specially for fixing in connection with manholes, and has at its inlet a short piece of open channel or half-pipe. The points to be observed about a trap for this purpose are that its parts shall be so formed as to facilitate the thorough scouring out of it when there is a flow of water through the trap; a slight dip at the inlet, which should be well rounded, also tends to add force to the water at its entrance.

A modification of this trap (fig. 154) has been devised by Professor Corfield with a view of giving greater effect to the scour of water through it by making the channel at the entrance to the trap somewhat of an egg-shape; but in this modified trap an arrangement has been contrived so as to form a bye-wash through the arm of the trap provided for affording access to the

drain below the trap. This bye-wash is furnished with a plug-valve having a chain or rod attached to it and brought up to the top of the manhole so that, in the event of a stoppage occurring in the trap and the manhole becoming in consequence filled with sewage before the stoppage is discovered, the bye-wash can readily be opened to allow the sewage to pass away until the level of the bye-wash is reached, when access to the trap can more readily be obtained for removal of the obstruction, and thus the necessity for pumping or baling out the manhole is removed.

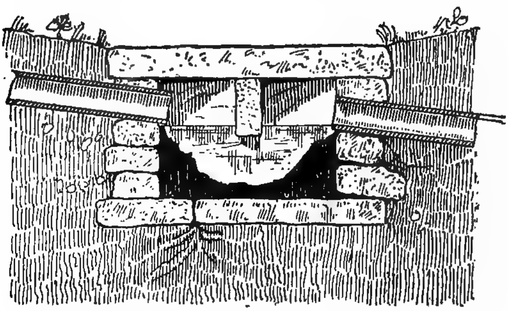


FIG. 152.

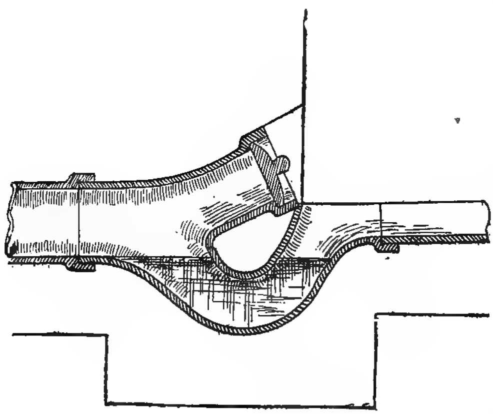


FIG. 153.

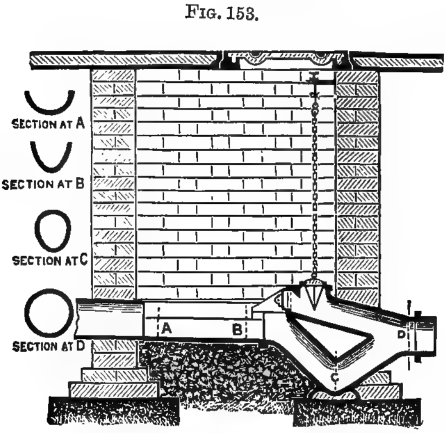


FIG. 154.

To receive the surface water from yards and other paved places, gulley traps are used. These traps should be as simple in construction as possible, and should certainly not be of the form known as 'bell traps.' In this trap (fig. 155) there is a fixed part which contains in the centre the open mouth of the pipe around about which is an annular space to hold water, and a movable part which consists of a grating and an inverted cup or 'bell.' The edges of the cup dip into the water contained in the annular space, and so form a water seal. The defects of this trap are that the water seal is very shallow, often not exceeding a quarter of an inch in depth, so that a very small amount of evaporation suffices to unseal the trap, and the movable part is apt to get removed or broken when the protection of the water seal, such as it is, vanishes.

For ordinary purposes, and where the water washed into the trap is not liable to be charged with sand or other solid matters to any great extent, a suitable form of trap is that shown in fig. 156; but where such solid matters are likely to be present in considerable quantities, a trap made as in fig. 157 with a receptacle for intercepting the silt &c. is more useful.

The bucket is made of iron and has a handle for lifting it out, and the surface both inside and out should be tarred and sanded to protect it from rust.

To prevent the passage of drain-air into a house by way of the waste-pipes of such fittings as sinks, baths, and lavatories, it is necessary to cause such waste-pipes to be absolutely separated from the drains and to deliver in the open air over trapped gulleys. In the model bye-laws issued by the Local Government Board for the guidance of local sanitary authorities it is provided that an open channel shall intervene between the end of the waste-pipe and the trap, and that the interval between the pipe and the trap shall be at least 18 inches. The object of this further provision is to make the break in the continuity of the waste-pipe and the drain greater, and so to lessen the possibility of foul air passing from the gulley into the waste-pipe, and also to render the end of the waste-pipe more accessible for cleansing purposes. For it must always be remembered that a pipe through which greasy water is constantly passing, as is the case both with scullery-sink wastes and lavatory wastes, is liable to become very foul with grease and soap and to require periodical cleaning. For this reason it will be seen, when the inside fittings come to be discussed, it is always desirable to have a trap upon the waste-pipe itself.

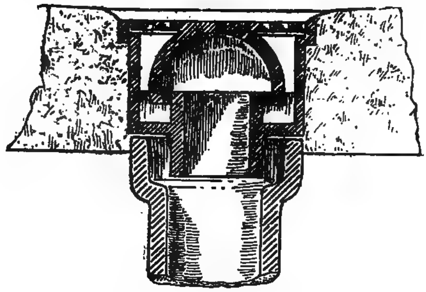


Fig. 155.

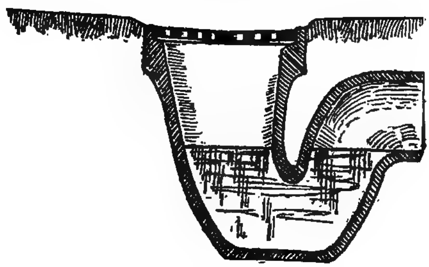


Fig. 156.

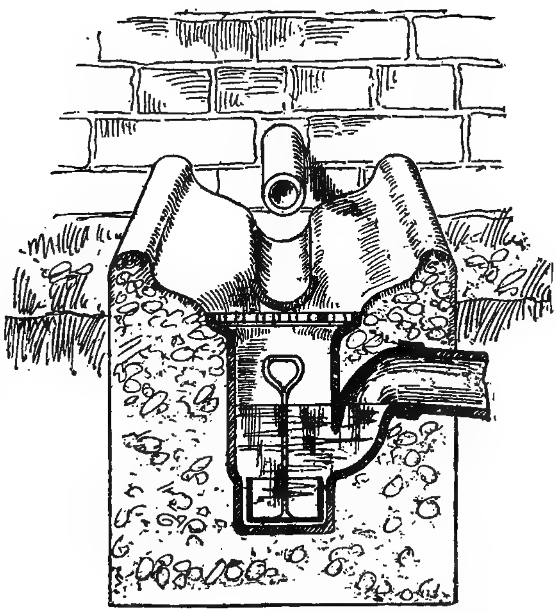


Fig. 157.

The trap into which waste-pipes from sinks discharge should be as

shallow as it can be made consistently with the provision of a sufficiently deep water seal, so that the body of water contained in it may be reduced as much as possible in bulk. A suitable form of trap is shown at fig. 158.

While the necessity for traps in proper places must not by any means be overlooked, it is equally necessary to guard against the undue multiplication of traps or the fixing of them in places where they are not required. For the existence of a trap necessarily means a certain check upon the velocity of the flow of water in the drains, and every trap which is not absolutely needful is an obstruction to the passage of sewage. Traps at the feet of soil-pipes, for instance, are not only unnecessary, but positively harmful, for they prevent the free flow of air up from the drain through the whole length of the soil-pipe which is so necessary a part of the ventilation of drains.

The practice of closing or sealing up traps which receive the ends of rain-water and waste-pipes is one which is at variance with good sanitation. When a trap is closed up, as in fig. 159, it is not only difficult to get at it when required for cleansing purposes, but any foul or decomposing matter retained either in the trapping water or against its sides will pollute the air in the waste-pipe and, of course, also that of the building.

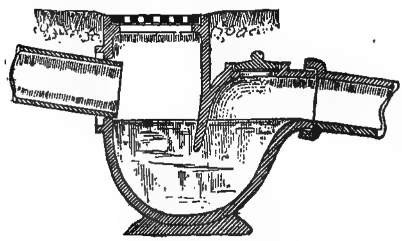


FIG. 158.

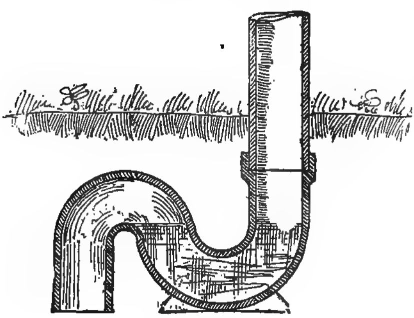


FIG. 159.

The regular and effectual scouring of drains depends, as a rule, upon the water which is discharged into them from water-closets, baths, and sinks—the water, in fact, which is used for the various domestic purposes in the daily life of the household. It is desirable, where it can be arranged, to supplement this by tanks provided for the express purpose of flushing out the drains with a larger body of water than ordinarily passes away from the houses through the various fittings; and where the drains have but slight fall some provision of the kind becomes a positive necessity. It is further desirable that the action of these tanks should be automatic, and for this purpose the annular siphon devised by Mr. Rogers Field, M.I.C.E., is most valuable. This apparatus (fig. 160) consists of a siphon the longer arm of which is placed within the shorter arm; the siphon is fixed in a tank in such a way that the longer arm passes through an opening in the floor and dips into a small body of water kept in place by a weir, and the shorter arm is kept clear of the floor to allow of the passage of water between the two. When the tank is filling, the water rises simultaneously within it and up the annular space in the siphon. When it reaches the top of the lower arm it is directed by a projecting lip towards the centre, and in its descent carries with it sufficient air to form a partial vacuum and thus start the siphon. These tanks are sometimes used also to collect waste water from sinks, baths, and lavatories, and so to concentrate, as it were, the flushing power of the water which would otherwise pass away in small

discharges. The siphons can be made in many different sizes and applied to tanks of from twenty gallons capacity upwards.

The pipes hitherto discussed have for the most part been those which are fixed below the ground; there are, in addition, some pipes, such as rain-water pipes and soil-pipes, which are fixed vertically against the outside walls, and for which the materials ordinarily used for undergronnd drains are unsuitable. Rain-water pipes are usually made of iron, lead being used only in the most expensive works, and where elaborate and ornamental work is required. Cast iron is for all practical purposes a sufficient and suitable

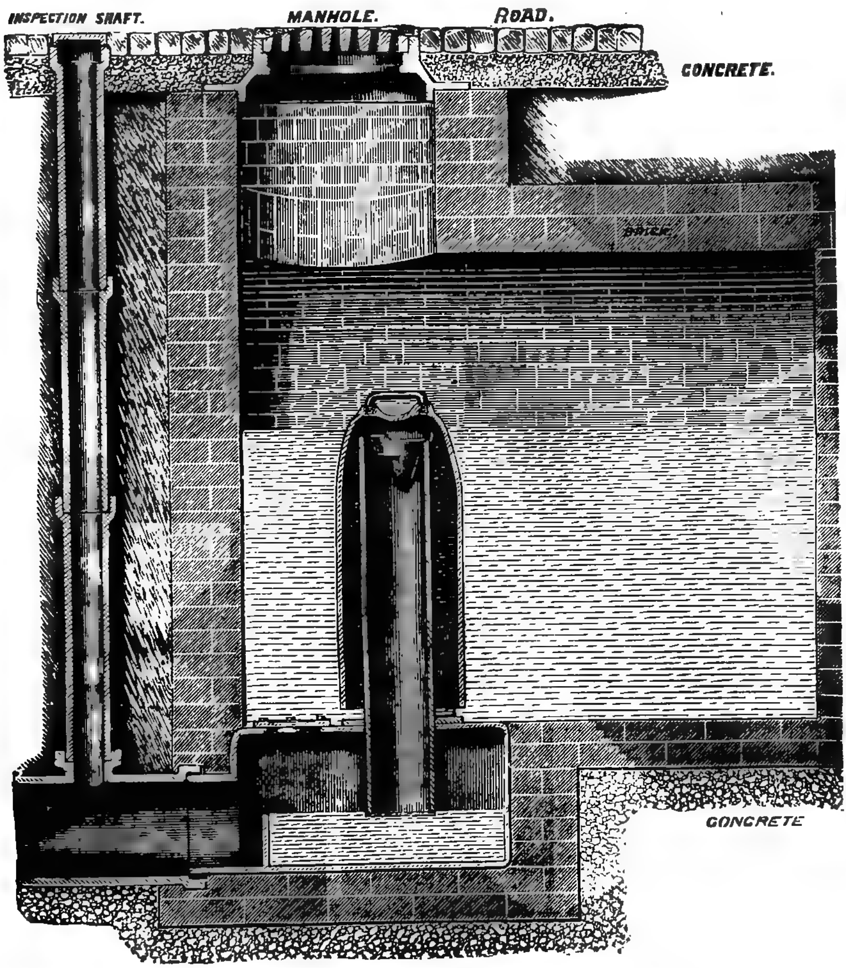


FIG. 160.

material for rain-water pipes. The pipes should be round, and should be fixed so that there is a free space of at least one inch between the pipe and the wall. The object of this is, first, that if a stoppage or a crack occurs in the pipe, as possibly may happen after frost, the water which leaks out of the pipe will not run down the wall and so cause dampness therein; and secondly, in order that the pipe can be painted all round.

For soil-pipes unquestionably the best material is lead. The pipe should be of the kind known as 'drawn,' in long lengths, made without seam and the lead of which it is made should weigh 8 lb. to the superficial foot,

which is equal to about ·136 in. in thickness. All the joints should be soldered and the pipe should be supported by properly made 'tacks' (or flaps of lead fastened to the back of the pipe) to the walls. Every soil-pipe should be connected directly to the drain, and should be carried up its full diameter as a ventilating pipe to a sufficient distance above the heads of all neighbouring windows. Opinions differ as to the best means of finishing the open end of a ventilating pipe, some authorities being in favour of cowls, while others consider that a simple open mouth is equally efficacious. The extracting power of the best cowls is certainly doubtful; and an efficient protecting cap may be made by widening out the mouth of the pipe to about twice its area, and fixing on it a spherical wire grating to keep the aperture free and open.

Waste-pipes from fittings on upper floors must also be connected to vertical pipes fixed outside the walls. These pipes should also be made of lead, and where hot water is likely to be discharged, the joints should be made to allow of expansion and contraction. These pipes should be ventilated, and the ventilating pipes carried up above the windows.

Ventilating pipes, whether for soil- or waste-pipes, need not be made of the same weight of material as the pipes they ventilate.

Cast-iron pipes, unless made of very heavy metal and provided with sockets strong enough to bear caulking with lead, should never be used for soil-pipes. The ordinary rain-water pipes so commonly used with the joints made of red lead are never air-tight as a soil-pipe should be.

The practice of discharging waste-pipes into rain-water heads is not to be commended. The inside of the head affords a lodgment for grease and becomes often very foul, and a source of nuisance very perceptible at the neighbouring windows.

Where it can possibly be avoided, soil-pipes ought never to be fixed inside a building. The common practice of fixing the soil-pipe in a chase in the wall, and then casing it over with a wooden casing, is a very bad one, and has been the cause of much evil. It has frequently happened that on investigating the cause of some serious leakage of drain air inside a house the evil has been traced to a hole made by a carpenter in driving a nail right through the pipe when fixing some piece of woodwork. Neither is it permissible to make one pipe do the double duty of soil- and rain-water pipe. In the first place, if this is done the rain-water pipe cannot properly be disconnected at its foot as it ought to be; and secondly, when the rain-water pipe is running full or nearly full of water during a storm, its function of ventilating the soil-pipe is necessarily in abeyance, and that at a time when it is most needed.

Water-closet apparatus may be divided into four classes:—(1) Those of the 'hopper' or 'wash-out' kind, which are simply basins with traps of earthenware, and which are flushed either by a waste-preventing cistern or by a valve fixed in the supply cistern; (2) pan closets; (3) valve closets; and (4) trough closets. The first three of these classes have been fully described in the earlier pages of this article, and it is here only necessary to describe the trough closet, which is an apparatus specially suited for outdoor purposes to public institutions (workhouses, schools, prisons, barracks, &c.), and to latrines in public places. It consists of a trough, made either in iron or in glazed earthenware, with a weir at the outlet end for the retention of a sufficient body of water in the trough, and a flushing cistern at the upper end. The trough should be round in section and should be slightly inclined towards the outlet, and the capacity of the flushing tank should be proportionate to the length of the trough, and should be automatic in its action. In most public institutions, but especially in schools, it will be necessary to

provide a grid at the outlet end, to prevent sticks or other things improperly thrown in from passing into the drain. A siphon trap should be fixed at the outlet end.

Urinals are more than any other apparatus the cause of nuisance from the difficulty experienced in keeping them clean. This difficulty invariably arises from an insufficiency of water. Urine, unless it is very copiously diluted, very quickly deposits its salts upon all the surfaces with which it comes in contact. One of the most successful forms of urinal recently introduced consists of an earthenware trough formed and flushed very much in the same way as a trough water-closet—with a shallower channel at the floor, also constantly flushed. In this apparatus the urine is received into a large body of water, which is periodically renewed from the flushing cistern, and then there is little or no chance of the surfaces being corroded. In all forms of urinal, whether for public or private use, it is important to provide that the urine is discharged into a large body of water, and that regular and automatic flushing is applied to the floor surface immediately under the basin or trough.

Sinks.—The particular form and material best suited for a sink is scarcely a matter which affects health conditions; but in all sinks the construction and destination of the water-pipe is hygienically a matter of great importance.

The mode in which the waste-pipe should discharge outside the house has already been described. It is not, however, sufficient to cause the waste-pipe to pass straight from the outlet of the sink into the open air. In most sinks, especially the scullery ones, a large quantity of grease is carried down with the water, and part of this is retained in the waste-pipe and becomes very offensive, and the smell is driven into the house by the cold air passing up through the open pipe. To remedy this a lead trap should be fixed immediately under the sink; and it should be provided with a screw cap either at the bottom or at the side for cleansing purposes.

In order to prevent the grease, which forms so large a part of the refuse water sent down from kitchen or scullery sinks, it is frequently collected in large tanks called grease traps. The advantage of this arrangement, especially in town houses, where the question of disposal of the grease is by no means an easy one, is open to doubt. A better plan would seem to be to provide a flushing tank whose contents should be automatically discharged with the trap which receives the water-pipe. By this means the grease is broken up and carried clear away by the force of water behind it, and has no chance of settling and clogging the drains.

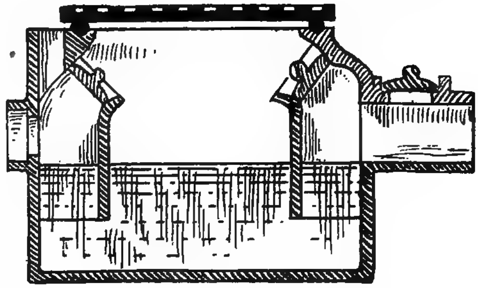


Fig. 161.

If it is thought desirable to collect the grease instead of discharging it into the drains, a tank made of vitrified stoneware or glazed fireclay provided with a movable air-tight cover should be used. The water from the sinks should be discharged through a pipe dipping a few inches below the level of the standing water, and the outlet pipe at the opposite end of the tank should be arranged in a similar manner. The grease as it congeals rises to the surface of the water and can then readily be removed. The inlet arm of

the tank should have a pipe brought up to the surface for ventilation. In order to empty the whole contents of the tank into the drain, an outlet is formed in the bottom provided with plug and washer and connected with the drain by a pipe.

The Examination and Testing of existing Drainage.—In examining the drainage and other sanitary appliances of a house, recourse must often be had to several modes of testing. Drains underground, for example, must be tested to ascertain if they are air- and water-tight, and this frequently has to be done without disturbing the ground. Vertical pipes must also be tested as to soundness, and the same test that is applied to an underground drain cannot always be applied to a vertical lead or iron pipe.

The tests most commonly applied to ascertain the condition of pipes are water, smoke, and oil of peppermint. The water test consists of filling the pipes with water, the lower end having first been securely plugged. This is the most severe test that can be applied, and any drain that stands the pressure thus applied may unhesitatingly be pronounced sound. The water test can rarely be applied in old houses unless—which is seldom the case—a manhole exists near the lower end of the drain, or it is possible to open the ground.

The smoke test can be applied either with the aid of a pumping apparatus or by inserting a 'drain rocket' into the course of the drain. Either of these methods can usually be applied without opening the ground or disturbing the pipes, but where the drain to be tested is underground, and covered over with earth and stone, or cement paving, the smoke test often fails to reveal defects which are readily detected by the water test. Smoke is specially useful for testing vertical pipes, and for tracing the source of smells arising from defects in pipes which are hidden in walls or behind casings.

Oil of peppermint is useful for detecting leaks in soil-pipes or in drains where they are under wooden floors and close to the surface; but when once it has been applied its smell is so pungent and penetrating that no second test can be made with it.

In examining the condition of the drainage and other sanitary appliances of a house, the first process is to ascertain, as nearly as possible, the general line of the drainage. Assuming that no manholes or inspection chambers are in existence, it will be necessary to dig down to the main drain and open into it. The existence or not of a disconnecting trap between the drain and the sewer must next be ascertained, and if a trap exists it is necessary to ascertain its form and construction. The next step is to test the main drain, either with water or smoke, to ascertain if it be water-tight. How this is to be done must depend upon circumstances. Should the test applied point unmistakably to the existence of leakage, the drain should be uncovered for its whole length, and the defective parts traced. All junctions should then be carefully examined. The vertical pipes will then be tested, care being taken when testing a vertical pipe with smoke to cover up any open ends. The waste-pipes from sinks, baths, lavatory basins, and safes under closets should next be examined, and note made of any such pipes which are directly connected with drains or soil-pipes. The overflow-pipes from cisterns must be traced, and the supply-pipes to water-closets investigated. Overflow-pipes are not unfrequently connected to soil-pipes, and the water supply to a closet apparatus is often found to be laid on direct from the cistern which supplies drinking water.

HOSPITAL HYGIENE

BY

H. G. HOWSE, M.S.

SURGEON TO GUY'S HOSPITAL

HOSPITAL HYGIENE

In former days a permanent unwholesomeness of greater or less degree was held to be a normal condition of hospitals inseparable from the aggregation of sick persons, and so generally did this view prevail that the word 'hospitalism' was actually used to express this thought, as if the circumstances of hospital life were necessarily prejudicial rather than favourable to the maintenance of health.

Experience has shown that this condition, if it be found in our time in any institution devoted to the sick, arises from one of two causes, or from both: either from the defective planning or construction of the building, or from mismanagement in its use; for it is possible, by errors in its administration, for any hospital, however well designed, to become prejudicial to its inmates, who are usually peculiarly susceptible to unhealthy influences.

The details of hospital construction and constructional arrangement of wards will not be dealt with in this article, but in that headed 'Hospitals and Public Institutions,' p. 718; it is proposed here to deal with minor details of ward-working.

Floor Cleaning

The material of the floor of a ward should be some fairly hard wood, prepared so as to be non-absorbent. Oak is one of the best woods, but it is very expensive; teak is also valuable for the purpose, but is little, if any, less expensive, and, though easier to work, is not quite so hard as oak. The planks forming these hard-wood floors should be dovetailed into each other, or tongued and grooved, as in parquet floors, so that there may be no interval in shrinking between the planks. It is best, if it can possibly be managed, to keep the wood which is to form the flooring of these rooms for two or three months in the room where it is to be laid, so that all drying and shrinking may take place before laying the floor. This is not often practicable; but, in any case, thoroughly dried and shrunk wood should be used, and the method of tongued and grooved floors gives good results. They are not, however, easy to remove in case of necessity, when gas tubing, &c., runs beneath the floor. This must be specially provided for by the planks being screwed simply into the joints over the pipes. In whatever way the junction of the planks is effected, it is important that there should be no space between the planks leading to the interval between the joists and the ceiling of the room below. Hard-wood floors, after laying, should be planed down level and then well sand-papered, using abundance of sand-paper. The fibre may then be further consolidated and rendered waterproof by using pretty freely over the surface a solution of shellac in spirit. This should be repeated two or three times, rubbing down with sand-paper between each application. This produces an exceedingly hard, durable, and waterproof floor, which is as dust- and germ-proof as it is possible to make it.

Deal is, however, the commonest material of which the floors of hospital wards are constructed, both on account of its price and of its ease of working. It is therefore necessary to consider the best mode of treating it in all the hospitals in which it already forms the material used.

If the better forms of deal be used, not much objection can be raised to it, especially if some special modes of preparation and hardening are made use of. The inferior and softer kinds of deal are objectionable, in that they become exceedingly porous and absorbent after much washing, and thus afford a basis for absorption of decomposing discharges, and even of foul odours.

As a rule, in our hospitals much too little attention is paid to the condition of the floors. If deal be used, it commonly shrinks considerably for some time after it is laid down, even when the quality of the wood is good, leaving long fissures between the planks. These fissures at first allow a great accumulation of dust, dirt, and flue to collect between the boards and the ceiling of the room below; and this can never be got at and removed. If the fissures remain open, this dust is liable to be blown up into the ward in a high wind, if the space below the flooring is properly ventilated (for the prevention of dry rot). This dust is often a means of re-infection, after the closure and most careful cleansing and painting of a ward. Gradually, however, after a considerable lapse of time these fissures tend to become closed, at any rate in all the more trodden parts, by a collection of dirt and débris in them. This is only a less objectionable condition than the open state, if the flooring be regularly washed. The collection of dirt in them, being continually wetted, forms a nidus of germ-growth which cannot but be regarded as undesirable. These fissures should be stopped in some way within three or four years of the first laying down of the floor (or at a later period) with some non-absorbent material. This is best and most easily done by thin strips of wood laid and glued into the fissures. If the flooring has been stained and polished from the first, the fissures will probably have been closed by cement worked into them. This cement is usually some form of putty of the same tint as the flooring, and mixed with the same gum-resinous varnish as that used for the floor. This is good, if the fissures be small; but when they become wide and gaping, the cement should be cleaned out and strips of wood substituted.

As far as the healthy condition of the ward is concerned, the writer believes that the stained and polished floor is far better than one which has to be continually washed. Objection is occasionally raised that the cleansing of such polished floors is a process of 'rubbing the dirt in.' There is not much force in the objection. A properly prepared polished floor leaves little, if any, space for 'rubbing dirt in.' And the writer, for his part, would far sooner do operations in a ward of which the flooring is kept clean and polished than in one where the cleanliness is obtained by continual washing.

In the preparation of a deal floor for staining and polishing, after filling all the cracks and fissures with strips of wood and cement, it should be well rubbed down with abundance of sand- or glass-paper. This process adds very much to the hardness of the floor. In doing it, minute particles of the sand or glass get rubbed off and embedded in the woody fibre.[1] If, now, this

[1] It is not generally known how very much this adds to the hardness of a wood. In wood turned and polished with sand-paper on the lathe, if any ornamentation has to be afterwards added, it is found that wood so polished takes off the edge of the fine-steel tools used in the process very much more quickly than the original wood, on account of the particles of silica embedded in the fibre.

Some years ago the floors of the wards in Guy's Hospital were cleaned with sand. This was good for the boards, but it had to be given up, because with the open fissures between the boards such a quantity of sand gradually accumulated on the top of the ceiling below, that sooner or later the ceiling gave way from the weight, and fell in great pieces into the ward below. With tongued and grooved flooring, however, this need never take place. It is probable that the sand-scrubbed flooring of the past generation was much more

surface be brushed over once or twice with a solution of shellac in spirit of wine, and in the interval between each application rubbed again with fine sand-paper, it will be found that even deal can be so much hardened and rendered so resisting as to become a very durable material.

Such floors, whether they are of deal or hard wood, may be polished and kept clean by being rubbed with a mixture of turpentine and beeswax (in the proportion of one pint to a quarter of a pound, melted together). But in the case of deal, it is well occasionally to repeat the application of the spirituous solution of shellac, say, once a year, so as to maintain the fibre of a proper degree of hardness.

Walls

The walls of a ward should be of hard plaster, capable of being well rubbed down and polished. No inequalities or cracks should be allowed to exist. The surface of the wall should be painted, so that it can be periodically washed, the paint being left with its oil (i.e., shiny) surface, and not 'flatted.' Or it may be covered with a coat of varnish. The cornice mouldings should be of the fewest and most simple description, or altogether absent, so as to present as few angles and recesses for the lodgment of dust as possible. If wood wainscoting or panelling is used, it should be of hard wood, and should be of the simplest possible description, with plain or rounded surfaces, and as few angles as possible. The surface should be treated in the same manner as that already given for the flooring. With the exception of the skirting board, which saves the wall from breaking low down from careless blows, wood is a very doubtful material for the construction of the walls, unless used absolutely plain. The tendency always is to ornament wood used in the construction of a wall, either by panelling or even carving, and this is not advisable.

The surface of a polished plaster wall should be washed down periodically (at any rate, once in three months) with warm soap and water. If there have been any doubtful cases in the ward, it is well to use a solution of carbolic acid (about 1 in 30) instead of, or in addition to, the soap and water. If it can possibly be managed, it is well to apply one thin coat of paint once a year. This is better than allowing a longer time to elapse and then applying two or three coats at once. It keeps the walls and woodwork in better condition, and provides for the stopping of any cracks or fissures which may be appearing.

The same principles should be applied as regards any pictures or other ornaments hung on the walls. As a rule, pictures, brackets for statuary, and other similar ornaments, form a nidus for dust, which is objectionable. On the other hand, they cannot be altogether excluded from a ward, as they give an air of cheerfulness and home comfort which must be conducive to the well-being of the patients. Pictures, therefore, should have the simplest possible frames, and should be glazed, so that they can be easily dusted and kept clean. They should be hung with picture wire, not cord, which attracts the dust. The same rules should be observed as regards texts or any other ornaments used about the walls.

The method adopted in the Johns Hopkins Hospital at Baltimore, U.S.A., of joining the walls with the floor by a concave moulding, so as not to allow

durable than the soap-washed one of the present. Continual soap-washing, where there is much treading, tends to a separation of the bundles of woody fibre from each other in a deal floor. This may be seen in any of the soap-washed deal floors in our older hospitals, and accounts for the ragged appearance which they often present.

any angle to exist for the accumulation of dust (which is with difficulty removed by a broom from the usual corner between the skirting board and the floor), is one worthy of imitation, but has been only rarely adopted in this country. The same principle may be applied to the angle between the wall and the ceiling.

In temporary hospitals and those in which cheapness is a great object, the walls are frequently white-limed. This produces a rough wall, liable to become dirty in all the parts within reach, and therefore requiring frequent renewal. The coating of lime, also, soon loses the antiseptic quality which makes it so excellent a material for use for short periods. It is therefore not well adapted for the walls of permanent hospitals. On the other hand, for ceilings its superior whiteness makes it a more desirable material than paint. Such surfaces can be readily renewed once a year, and though the roughness is an undesirable quality, yet the bright appearance which a freshly white-limed ceiling gives to a ward adds to its cheerfulness and consequently to its healthiness.

The Beds

All bed linen should be frequently changed. Though no rules can be laid down how frequently this may be necessary, yet it may be roughly stated that it should be done once a week in every case, and very much more frequently in those in which the secretions or discharges are abundant or offensive. The woollen blankets and coverlets should also be frequently washed and aired, or even baked at a dry heat of 300° Fahr., if the case is a doubtful one. All dirty linen should be stored in covered baskets outside the wards, or in closed tin-lined boxes inside the ward, if there are no conveniences for storage outside the ward. The former plan is best, because it permits free access of air to the dirty linen. The boxes or baskets should be emptied every day, and the contents taken to the laundry, where they should first be disinfected by being placed in a large tank of antiseptic fluid. If they be very dirty, or much soiled with blood or discharges, a previous soaking in pure water is best. The use of solution of carbolic acid or any other antiseptic for the first soaking tends often to *set* the discharge in the fibre of the material, and thus to render more difficult the subsequent cleaning. This is often the cause of the complaints made alike by Sisters, nurses, and patients against hospital linen, viz., that it does not return so clean and white from the wash as the home linen does. The clean linen for the beds is brought into the wards once or twice a week, and may be safely stored in cupboards or boxes within the wards.

Draw-sheets and macintoshes used to protect the bed should especially be frequently changed, and it is questionable whether it is advisable to mix draw-sheets from offensive cases with the other bed linen from the ward. The macintoshes should be those macintoshed on both sides, so as to present a smooth, shiny surface on either aspect. These can be easily washed and purified, and are besides much more durable and economical. Those macintoshed between two layers of cotton stuff, and thus presenting the rough cotton fibre texture externally, are very objectionable. They easily become stained and dirty, and are difficult, if not impossible, to purify.

Splints used in surgical cases must be carefully washed and purified after use. Those of wood should be washed with a solution of corrosive sublimate and occasionally rubbed over with fine sand-paper. With these precautions, the splints do not now become infested with vermin as they used to, even as recently as twenty years ago. Consequently, there is no necessity for

using any medicated wool for the pads of these splints, and plain cotton wool or tow is the material generally used. Oakum or tenax, which was formerly much used, stains the splints, and often the bed linen, by reason of the tarry material contained in it soaking through. These materials are not therefore now much in favour, and the necessity for them has mostly disappeared since the careful purification of the splints. Nevertheless, any pad may become accidentally infected from the patient's clothing, especially in a case of accident, and hence these pads should be changed as frequently as opportunity permits, and always burnt directly after use.

The bedsteads should of course be of iron, painted or enamelled, so that they can be easily kept clean. Wire-woven mattresses are now much more frequently used than formerly, though the ancient sacking, if kept sufficiently tight, is not a material to be despised. It gives a certain springiness (as in hammock beds), and is a material easily changed and purified. For fracture beds, boards placed below the mattress are necessary, but they should be washed with a solution of corrosive sublimate occasionally to prevent the old trouble (inherent in all wooden structures) of their becoming infested with vermin. The mattresses and beds are usually stuffed with flock, and this is probably the best material that can be used in all large hospitals where expense has to be considered. It has the advantage of being a cheap material, and the beds are very easily purified and restuffed.

Flock beds can be changed if necessary with every new patient, and the old bed sent to be cleansed and disinfected by superheated steam at a temperature of 300° or 350° Fahr. The flock is generally hand-picked through before this, and any very bad pieces not easily cleansed are removed and destroyed. Hence the advantage of a *cheap* bedding material. Hair mattresses, as a rule, though better for many cases, are too expensive both in material and working (when they have to be disinfected) for general use. A hair mattress, if it has to be disinfected, has to be pulled entirely to pieces to accomplish the process satisfactorily. Attempts have been made at various places to disinfect a hair mattress *en masse* by subjecting it for a long period to both dry and moist heat at a temperature of 350° F. It has been found that such a long exposure is necessary in order to penetrate adequately the structure of the mattress, and that the texture becomes greatly damaged in the process. Hence this mode of disinfection has been abandoned. The picking to pieces of a hair mattress and re-stuffing it is a much more expensive process than with the flock bed (to say nothing of the difference in the original cost of the material), and hence we have a very powerful argument in favour of the flock. If, however, for any reason hair mattresses are used, the plan adopted at the General Lying-in Hospital, referred to later on (*vide* p. 802)—of having a register of mattresses, each one ticketed and numbered, and only sent away for purification when any doubtful case has occurred with it—is a good one.

Dresses of Attendants

The Sisters and nurses should be dressed in some washable material. In general hospitals clerks and dressers will usually wear their ordinary woollen clothing; and the medical attendants in England almost invariably do the same. In many of the Continental hospitals, however, the medical staff change their outer clothes on the visit to the wards to a suit of some washable material. In operating, again, there is very great variety of practice amongst surgeons even in England. Some assume a special operating dress of washable material; others a special macintoshed, shiny garment, which can

be easily washed down and purified. The great majority of English surgeons continue to wear an ordinary woollen operating coat, with perhaps a macintosh apron and sleeves. At the present time there is a tendency in favour of the Continental plan, viz., to adopt some washable material for operating in. The writer is of opinion that the use of this will depend in the future very much upon whether the carbolic spray is retained or discarded in practice. If it is retained, he thinks that the woollen coat becomes absolutely innocuous by constant use in it. The sleeves and every other part become so impregnated with carbolic acid in vapour and solution, that practically the blood which gets on to the garment dries without decomposing. This may be shown by mixing blood and carbolic lotion (1 in 30), or even pus and carbolic lotion, together, and spreading them out in a fairly thin layer to dry. The mixture dries into a leathery material, composed of coagulated albumen, fibrin, blood-corpuscles, &c., which refuses to decompose in the ordinary sense of the term. No doubt it undergoes chemical change, but not of a kind prejudicial to subsequent operations. Even offensive cases, e.g., cases of decomposing pus in abscesses such as occur in urinary or fæcal abscesses, may be operated on safely with an abundant carbolic spray (used as an irrigant) in such a garment. But the treatment of such patients comes under the head of infectious cases, rather than under that of ordinary aseptic surgery. Still, every surgeon must necessarily treat such cases in the course of ordinary practice, and often in wards mixed with other patients. If obliged to do so, he will naturally put off such cases to the last, and he will be careful not to use the coat again until it has been thoroughly aired and dried, i.e., for at least twenty-four hours. With these precautions, the writer has never seen any mischief result from the use of the ordinary woollen coat. In our variable climate the use of this garment is so much more comfortable, so much warmer and safer for the operator, as compared with the thin, washable, generally linen or cotton garment usually substituted for it, that its use will probably be generally maintained.

On the other hand, if the carbolic spray is given up, the writer is of opinion that there is increased need for the washable garment, whether it be of linen or macintosh, both for operator and for dressers. In these cases asepsis is generally maintained either by continuous irrigation during the operation from a large syringe or cistern, or by washing the wound out after the operation is over. For reasons given subsequently (*vide* note, p. 788) the writer regards neither of these alternatives as perfect. And, as far as the dress of the operator and his assistants is concerned, they are absolutely ineffectual. The air is no longer full of a fine antiseptic rain; there is no wetting of the clothes; and though this may slightly contribute to the comfort of those about, yet the risk must be very perceptibly increased. For these reasons the tendency—very visible during the last year or two amongst those surgeons who have abandoned the use of the carbolic spray—to adopt a special washable dress for operating in must be regarded as a good one. But if the rule is to be effectual, it must be extended to the assistants as well as to the operator himself.

In very septic operations, and all those performed on infectious cases in isolation wards, a special external suit of clothing should be worn, which should be kept solely for this purpose. In isolation hospitals, or wards of large size, where many infectious cases are associated together, this rule should be extended to the visit also. This applies, of course, to dressers and house surgeons as well as to the visit of the medical or surgical staff.

Visits of Friends to Patients

There can be no doubt that, though in all large general hospitals it is absolutely necessary to allow these visits, they yet introduce a very considerable element of risk into the sanitation of the ward and into the treatment of the patients. On several occasions the writer has seen infectious diseases brought into hospitals by visitors coming from infected homes. There seems absolutely no practical or workable plan of preventing this. It is no use questioning the visitors before admission. Their eager desire to see their relatives or friends in the hospital, or their crass ignorance as regards what constitutes an infectious malady, makes them either regardless of the truth or misleading in the expression of facts. Moreover, it is not possible to exclude the relatives from hospitals or wards where surgical operations have to be performed, because were this done a cry would speedily arise, especially in cases which terminated unsuccessfully, that the patient had not been treated well, that barbarities had been practised, &c., &c.—unfounded rumours such as have been propagated many years ago, either by ignorant or malicious persons, in respect to many hospitals. Such rumours and unfounded accusations can only be prevented by allowing the relatives and friends moderately free access to the patients during their treatment. The great confidence with which the public, both educated and ignorant, now treat our general hospitals—a confidence which even the violent and widely spread slanders of anti-vivisectionists and other fanatics have failed to shake—is largely due to the friends and relatives being allowed to see patients, and thus to form some idea for themselves how they are progressing, and how they are treated. Still this introduces an element of risk from the cause mentioned, and it is a subject of anxious consideration how far these risks may be minimised without altogether preventing the visits. In all general hospitals of late years a tendency to diminish the number and length of the visiting has been apparent. Thus at Guy's Hospital there used to be three visiting days a week; now there are only two. At the Evelina Hospital for Sick Children there used to be two, but now there is only one day a week. And in both hospitals the number of visitors to each patient has been strictly limited of late years. Thus at Guy's, not more than three visitors are admitted at once to see the patient; at the Evelina only one at a time. It will be seen that the rule is much stricter in the children's hospitals than in the adult. This has arisen from necessity, on account of the much greater risk of importing infectious diseases amongst many children congregated together than amongst adults. The writer has seen on so many occasions measles and scarlatina break out in children's wards after the visit of some friend or relative from an infected home, and the results are so disastrous, especially in surgical wards where nearly all surgical operations have to be suspended during the epidemic, and the ward practically closed—at any rate to all fresh patients—that it would appear as if no rule were too strict to prevent the occurrence of these outbreaks. It is for this reason that the number of visiting days each week is restricted to one, and that only one friend at a time is admitted to see the patient. Even with this amount of visiting, epidemics still sometimes occur. And it must be manifest that they could never be entirely prevented, even were the friends excluded altogether, because there is always the risk of a fresh child being admitted to the ward from an infected home, the previous surroundings of each freshly admitted patient being of course quite unknown.

In isolation hospitals it is the rule not to admit any friend to see the patient during his residence in the hospital, and it must be manifest that no

relaxation of this rule could in any way be permitted without the risk of spreading contagion, at any rate in the majority of infectious diseases admitted into these hospitals.

Patients' Clothing

The clothes in which a patient is admitted into hospital must be treated according to the state in which they are found. If very dirty, they should be sent back home by the patient's friends. This would be the best plan in all cases, and is indeed adopted at certain small special hospitals; but in large general hospitals it has been found that the sending for the clothes involves so much delay when it is desired to discharge the patient, especially when the friends do not particularly wish to have him home, that some plan of keeping the clothes becomes absolutely necessary for the good working of the hospital. This is best done by keeping each patient's clothes in separate bundles in large closets outside the ward. Each bundle should be separated from the others by a wooden or metallic partition, which can be easily taken out, and the whole place frequently washed out. If wooden shelves and partitions are used, they should be wetted with a solution of mercuric chloride before being replaced, so as to prevent vermin. If the patient's stay in hospital is likely to be a long one, soiled linen, &c., had better be washed before being put away, and if there be a suspicion of vermin, the clothes should be subjected to the dry-heat process before being placed in the closet. Indeed, in some hospitals this is done with nearly all the clothes which are kept. And it must be admitted that this question of patients' clothes is often one giving much trouble, and requiring a good deal of discretion on the part of the Sisters and nurses. The closets and trays especially require continual overhauling, to see that everything is kept as clean and unobjectionable as possible.

The clothes of a patient suffering from an infectious disorder must, of course, be thoroughly disinfected and cleansed by one of the methods mentioned elsewhere before being put away. Such clothing should be kept by itself, and not allowed to mix with that from ordinary patients.

The writer does not here refer to the clothing to be worn by the patient during his stay in the hospital. This will of course vary according to the nature of the case. In a few hospitals it is provided by the institution itself, but in large hospitals more generally (and in the writer's opinion more suitably) by the patient himself. Still, if the patient be very poor, it may be necessary to provide more or less clothing in this way. And in most children's hospitals in London a certain amount of the patients' clothing while in bed is almost invariably provided by the institution—perhaps more to give a pleasing uniformity to the ward than with any actual charitable intent.

Lockers

In nearly every hospital there is provided for each bed a locker, which serves partly as a table, partly as a small cupboard in which patients can place things. Though in most hospitals it is regarded as an almost necessary adjunct to the bed, conducing to the comfort of the patient and to the tidiness of the ward, yet it is one of the most doubtful articles—hygienically considered—which a ward can contain. It is sometimes used for food, sometimes for articles of dress, books, &c., sometimes as a receptacle in which the small pot used for urine or expectoration is hidden away. Nothing can be nastier than this combined use of the same receptacle, even though it may take place at different times. Those who know the peculiar saturating effect

which a pot of warm urine has upon a commode, however carefully painted (or polished if of a hard wood) its interior may be, will understand what the writer means. Good housewives even object in a well-ordered bedroom to the *pot de chambre* being placed after use under the bed, especially if the bed has a steel spring mattress, on account of the gradual rusting effect of the vapour arising from the warm urine on the metal. If, therefore, one patient uses his locker for urine, it will be impure always afterwards, unless repainted in its interior. The greatest vigilance of the nurses is unequal to meet this abuse. The writer has seen surreptitious food stuffed into these lockers during visiting hour removed by the nurse examining the locker after the visit was over, and yet an hour or two later more food has been found in the locker. Many of the patients act in ignorance of the rules existing in most hospitals on this subject. Many more act in wilful defiance of these rules, and nearly all are quite ignorant that these rules are made for their own protection and good. It is not easy to see how the evil can be remedied, except by the complete abolition of the closed locker and the substitution for it of a small table with open shelves below, whereon the nurses or Sister can see at a glance everything they contain. In the furnishing of all new hospitals it is to be hoped that the locker of the future will take this form. It will involve some sacrifice of tidiness, but this will have far more than compensating advantages. Even upon the shelves of these tables the urine pot should not be placed. Every urine receptacle should have a small painted wooden or metal cover closely fitting to the top, and it should be a rule of the ward that this cover should be applied directly after use. The pot may then be placed safely below the bed or upon a special shelf on the wall near the bed. But with the cover there is really no objection to its being placed under the bed. During the time of cooling of the urine any steam arising condenses on the cover, and all harmful effects on the bed are prevented. The cover also excludes dust, &c., from the urine, and thus renders its chemical examination afterwards (should that be necessary) so much the more satisfactory. As far as expectoration is concerned, nothing can be better than the small earthenware pots with funnel covers in use in the wards of most London hospitals. In the case of fæcal excreta, it need scarcely be added that of course they should be removed as soon as passed, and that it is always desirable to keep a small quantity of some rapidly deodorising solution in bedpans, slippers, &c., so as to mitigate the nuisance of smell in a ward where the patient is obliged to relieve himself in bed.

The keeping of food in lockers cannot be too strongly deprecated. In some hospitals it is the custom to give out the day's allowance of bread, butter, milk, &c., to the patient in the morning, and this is kept in the locker till consumed or taken away. For the reasons given above, this should never be allowed. All food should be kept under one common control, should be served out fresh to each patient at the meal time, and the remnants taken away afterwards. Nothing can be worse for the sweetness and freshness of the food than the constant standing of small quantities of unconsumed food (such as bread, milk, &c.), whether in or outside a locker, by the patient's bedside all day. Nothing can more surely tend to the taking away of what appetite he may have than the constant sight of such food. In many hospitals, again, it is the rule for patients to provide their own grocery. Even this is to be deprecated. But where the poverty of the hospital resources renders this absolutely necessary, it is best that the grocery should be placed in a *small* drawer in the table—a drawer too small and too shallow to contain urine or any objectionable article.

Dressings

Dressings are best kept in a ward in a cupboard or box by themselves. A movable table (running on wheels with indiarubber tires), fitted with drawers and small cupboards, is the best receptacle for the day's dressings. Antiseptic dressings, where the dressing contains a vaporisable chemical (as carbolic acid, oil of eucalyptus, or iodoform), should be kept in an air-tight tin or tin-lined box in the table. This is not of so much importance where the antiseptic is fixed, as in sal-alembroth gauze and wool (corrosive sublimate). But even here the material should be all kept together, packed away tightly, so as to exclude dust as much as possible.

In many wards devoted to purely surgical patients it is most convenient for the nurses to cut the daily dressings necessary for each patient some time before the actual dressings are done. For this purpose it is best to have several pieces of American cloth, made with flaps at the edges (as in music portfolios), and lined with some waterproof material (not macintosh), such as 'waterproof muslinette.' In these the dressings for each case can be tightly rolled, and tied with coloured tape. The dressing necessary for each case can then be laid by each bed, and await without harm the visit of the surgeon or dresser. In this respect nothing can be worse than dressings cut some hours beforehand and lying about unfolded, or only loosely folded, exposed to the air and to the access of dust. If the antiseptic is vaporisable, such treatment of the gauze simply spoils it, and is the cause of many failures in the aseptic treatment of wounds. If it is fixed, though it may not be so prejudicial, yet the free access of dust will imperil the success of the case.

Where the spray is employed, the top of the dressing table may be used for it, and for a dish of antiseptic lotion for instruments or for washing wounds. Many surgeons do not now use the spray, but trust to asepticising the wound after the operation is over by irrigating it with corrosive sublimate solution or some other antiseptic. The writer has not himself abandoned the spray, though he recognises that there are disadvantages attached to its use. These, however, may be minimised if their existence is recognised, and they appear to him to be altogether less than the very serious evils which may arise from its non-use.[1]

[1] As regards the use of the carbolic spray for operations, it may be thought after the very explicit declaration against its utility by its inventor, Sir Joseph Lister, at the Berlin International Medical Congress of 1890, that it would naturally fall into disuse. This is no doubt largely the case, but it is not in accordance with the writer's own views about it.

There are two ways in which the spray may be used: (1) as a vapour; (2) as an irrigant. Sir J. Lister has always used it in the first, the writer in the second way. To obtain the first, the spray is placed at a considerable distance from the patient—a distance sufficiently great to allow the minute globules of carbolic lotion to evaporate into the air before reaching the patient, thus producing an atmosphere charged with carbolic acid, in which it was believed no germ can live. To obtain the second, the spray is placed only a short distance from the patient (2–3 feet), so that the finely divided globules of carbolic lotion shall fall directly upon and *wet* the wound. The use of the spray in the first way is undoubtedly a delusion. It sounds scientific to disinfect the whole of the air about the patient and the operator, but the writer has convinced himself that it is not practicable. Germs may remain untouched in this antiseptic atmosphere, and may fall on the wound, and produce the usual septic trouble afterwards. In the second way, although germs may still fall upon the wound untouched in the midst of the spray, yet they fall upon a surface wet with the antiseptic, and they are therefore quickly destroyed. No doubt the irritating action of carbolic lotion is rather greater, when used as an irrigant, than when used in the first way; but this disadvantage is more than overbalanced by the greater security obtained. It may be said, Why then not make use of carbolic lotion to irrigate the wound at the end of the operation, instead of using such a cumbrous

While upon this part of the subject, it is necessary to utter a warning about the neglect of antiseptic precautions, which may very likely arise in the future, even if it is not already beginning in some hospitals. In the way surgery is now practised, medical students of the present generation have had very few opportunities of seeing the results of septic wards in our large general hospitals. The cases do so well, with such little disturbance from septic causes, that there is great risk that the surgeons of the future may get to disbelieve in the very serious risks which the want of observance of antiseptic precautions will entail upon them. The risk is the greater because there will be no sudden change from surgical results, as they now are, to the results of thirty years ago. In looking back over this period it can plainly be perceived that the introduction of antiseptic surgery did not work any *sudden* transformation in hospital wards. For a long time the *principles* of antiseptic surgery were in doubt, and were only practised by one or two surgeons here and there. An aseptic case or two lay amongst many others mixed all together in the wards. Nevertheless, even those few had a certain influence

method as the spray? There was great weight in the argument made use of, the writer believes, by Sir J. Lister, on his first introduction of the spray, though since then seldom heard, viz., that during an operation, when making successive incisions, especially amongst the muscles, the parts retract unequally, and thus dust-germs are apt to get tucked away into secure recesses of the wound, which are never reached by irrigation performed after the operation is over. This risk is avoided if continuous irrigation by the spray is going on during the whole performance of the operation.

Irrigation in some form is nearly always practised by those who have given up the use of the spray. But here again there is great difference of opinion as regards the antiseptic to be used, and as to the strength of the solution. Corrosive sublimate solution is that most in use at the present time, but it is sometimes employed at a strength of 1 to 1,000, sometimes at 1 to 10,000, and at all degrees of strength between these two. This very great divergence in the practice of surgeons is likely to engender carelessness and disbelief in the minds of those who are now studying surgery for the first time. From what he has seen, the writer does not believe in the efficacy of solutions of 1 o 10,000. While admitting that there may be some range of variation in different cases in the strength of the solution we employ, the writer thinks that the minimum strength should be 1 to 2,000, and that a strength of 1 to 1,000 will prove the right one in the great majority of cases under treatment. For the reasons already cited, the bad results of employing too weak solutions will not very obviously appear at once.

As an instance of what harm may result from the employment of too weak solutions, the writer may state what took place some years ago within his own knowledge at a children's hospital in the comparative infancy of asepsis. For some months there was failure in the aseptic results of operations. Inquiry was made at different times in very various directions to try and account for their failure. The goodness of the gauze was suspected; the hygienic surroundings of the patient, the conditions of the operator, nurses, and house surgeon were inquired into. Again and again the strength of the antiseptic solution was challenged, but the dispenser always sent in the assurance that it was right. This went on for so long that at last the writer was almost inclined to admit that children's tubercular joint operations (in which principally the failures took place) were more difficult to keep aseptic than the same cases in the adult. Finally, it was discovered by the energy of a new house surgeon (Dr. Henry Davy, now of Exeter), and this only by absolutely standing over the dispenser, and watching him make it, that by some curious perversion of arithmetical calculation he was sending up the carbolic lotion to the wards, instead of a strength of 1 in 20, something more like 1 in 100, so that the antiseptic made use of was almost indefinitely weak. The writer believes this was done entirely *bonâ fide*, and was due to a failure of arithmetical calculation, which once wrongly carried out repeated itself each time in the dispenser's mind. Another similar failure in the preparation of an antiseptic solution of right strength the writer detected in another place by having himself made many times the preparation, and noticing the difference in that supplied. This again was due to a wrong arithmetical calculation—only in this case it was not attended with such serious results.

It is not within the range of this article to discuss the strength of other antiseptics, nor the varieties of wound or operation in which each different antiseptic is of most use.

on the well-being of the rest, and, as they increased in number, the chances of the rest of the cases, not treated on antiseptic principles, perceptibly improved. This was because there was a smaller proportion of foul air-infecting cases in the ward; the surroundings for all the patients became more hygienic, and consequently they did better. If we imagine a ward of thirty patients, twenty-nine of whom were aseptic cases and one treated (say an amputation) without recourse to antiseptics, it is clear that this one patient would have a much better chance of escaping septicæmia than if he were one in a ward full of septic cases. Similarly, at the present time, a single case, or more, may be operated on in our wards without recourse to antiseptics, and yet may do well, because he is surrounded with healthy cases. Thus may arise the risk of the future. A young surgeon, never having seen the deplorable results of surgery as older surgeons saw them thirty years ago, may operate without the use of antiseptics, and may possibly be able to point to case after case being operated on successfully, until he begins himself to enunciate as a law his conclusions that antiseptics are unnecessary, and that surgeons have been labouring under a great delusion in the past as regards their use. There is very little doubt that his results in the process of time will undeceive him, or at any rate those watching these results. But this will entail a considerable loss of life, and an amount of suffering to individual patients, which will only be prevented by careful attention on the part of medical students and teachers to the *history* of the surgery of the past thirty or forty years.

Instrumentation

Under this heading is included the keeping of instruments used in dressings and operations clean and ready for use. The instruments got ready for any particular operation should be placed in a shallow tray containing antiseptic solution shortly before the operation takes place. After the operation they should be at once cleansed from blood or discharges by washing in cold water. They may then be sterilised by placing in boiling water for a short time. For steel instruments with a cutting edge this period should at the outside scarcely amount to two minutes, or the edge and the polished surface will be dulled. Each instrument should then be quickly dried and polished before being put away. If the instrument be composed of metal and some other material, such as an ivory or wooden handle, only the metal part (as far as possible) should be immersed in the boiling water. Repeated immersions of wood or ivory in boiling water spoil them and loosen the attachments. Moreover, it is unnecessary; the immersion of the handle in the antiseptic fluid immediately before the operation sufficiently asepticises it, and prevents the carrying of germs from one patient to the other. Most probably this immersion will also asepticise the metallic part, but this is more doubtful. Most steel instruments have minute crevices and crannies (e.g., the serrations of artery forceps or minute depressions where spots of rust have accidentally eaten into the metal, &c.); these become filled with coagula of blood during the operation, and these are exceedingly difficult to detach by the cleaning process. Moreover, each of these little masses of coagulum is exceedingly difficult to sterilise by mere immersion in an antiseptic solution. The outside layer of coagulated albumen resists the action of the solution, and, as the mass adheres very strongly to the metal, germs may remain unacted upon until accidentally set free by the next operation. A small metal (brass wire) brush, used by artificers in one of the steps of brass polishing, is exceedingly useful in cleaning out the teeth of forceps and other minute depressions in metal instruments. But even when all these

precautions have been used, the writer has frequently seen most carefully cleaned instruments, when next put to soak in water or antiseptic solutions, throwing out from some invisible crevice blood-pigment, which slightly stains the water ; thus showing that, in spite of the care used, some red blood-corpuscles were left unaltered on the instrument, and that these have become ruptured by endosmosis from the fresh soaking in water, and thus may very possibly be centres of infection in any fresh operation. On the other hand, if the metal part of the instrument be subjected for two or three minutes to the heat of boiling water, from the conductivity of the metal for heat each of these little masses becomes of such a temperature that it can scarcely escape sterilisation.[1]

The only objection to the heating process is in the case of knives used for very delicate operations, where the temper is a matter of considerable importance. The degree of heat (212° F.) may have the effect of altering the temper to a slight extent, and thus deteriorating the edge. With large knives and scalpels, the alteration is not of such degree that it should be allowed to be of sufficient importance to warrant its non-use from this cause. With a few eye-instruments (cataract knives, &c.), their small size, and the very perfect piece of metal of which they are composed, make it possible to keep the whole of the surface at such an exceedingly high degree of polish that the precaution may not be so necessary in their case. But in all other cases the precaution is an essential one. In the majority of surgical instruments it must be manifest that there cannot be the slightest objection to their sterilisation by heat. Directors, probes, retractors, all kinds of bone forceps, small saws, trephines, elevators, and a vast number of other instruments can all be most easily sterilised by its use. It is especially essential in those which are actually used upon the flesh of the patient. I need only instance artery forceps, the serrated teeth of which need the greatest care. Again, tracheotomy tubes are instruments to which the heat-sterilising process can be most advantageously applied. And there is no class of instrument in which the absence of this precaution is attended with more dire results. In years gone by, when the disinfection of instruments was less thought about than at the present time, and when less was known about the causation of disease, the writer has seen numerous cases of tracheotomy followed by fatal results from diphtheritic infection of the wound, arising from the metal tracheal tube not having been perfectly sterilised after having been previously used in an infectious case. Thus a tracheotomy might be done for a case of scalded glottis ; the child would do well for a day or two, then develop a diphtheritic exudation about the wound, which would rapidly spread to the scalded glottis and the trachea, and the child would die from this cause.

Though diphtheritic tracheotomy wounds cannot even now be wholly prevented (a case arising every now and then, when the operation has been performed for diphtheria of the larynx, either by auto-infection or by extension of the diphtheritic inflammation from the throat downwards), yet it is probable that the much greater success which attends tracheotomy now than when the operation was first introduced is due for one reason to the much greater

[1] A word must be said here in favour of the surgeons of the future learning something of artisan knowledge respecting the manipulation of their instruments, and the materials of which they are composed. It will be found very useful. Many surgeons are no doubt accomplished mechanicians, but amongst many others there is a tendency to look with contempt during their earlier years in the profession (when alone they have time to acquire the knowledge) upon any knowledge of this kind. This is a mistake. As far as the antiseptic treatment of instruments is concerned, they may be kept much more perfectly aseptic if the surgeon is willing to look after them himself, and has the requisite amount of knowledge as regards the treatment of the material of which they are composed.

care which is taken in the disinfection of the tubes than formerly. In the instruments used on the alimentary or genito-urinary mucous membrane the disinfection of the instruments is of very great importance on account of the frequent infective character of the discharges. As far as these instruments consist of metal, no difficulty will be met with in purifying them ; but in the case of gum-elastic instruments, whether they be throat bougies, rectal tubes, or catheters, there is considerable difficulty in knowing what to do. They cannot be sterilised by heat without injury. Although it is a common practice to dip a gum-elastic catheter into hot water to soften it and render it more flexible, yet mere hot water is not sufficient for sterilisation. Nothing less than a boiling temperature continued for a minute or two will be sufficient for the destruction of germs, and it will be found that to boil gum-elastic instruments for this time is equivalent to their very rapid destruction.

Many antiseptics soften and destroy the gum resin which gives the smoothness and polish to the outer surface of these instruments. The writer is convinced that the common fashion of wrapping a gum-elastic catheter in a piece of carbolic gauze is very prejudicial to the catheter, rendering it sticky and causing the loss of its polish, besides being of doubtful utility as an antiseptic. Probably the better course is to dip the catheter in a watery solution of corrosive sublimate (1 in 1,000) for a minute or two before use. But for all hollow gum-elastic instruments it is best to burn them directly there is the least suspicion of their integrity. The inner bore of all such instruments is exceedingly difficult to purify satisfactorily, after they have been used for cases in which blood or pus gains access to the interior. And although this surface does not come into absolute contact with the mucous membrane of the patient, yet it may easily be a source of infection, if there be any impure material adhering to it. Even with a silver catheter, it must be a matter of every-day experience to surgeons how difficult it is to clear away the last traces of blood-clot from its interior. Though it may have been soaked in water, and blown through, and raked out with the stilette, though even a current of water may have been run through it, the surgeon will not infrequently find, after drying and polishing, that when again put into fresh water before use a slight colouration issues from its interior. These catheters, however, can be easily sterilised by heat, and it is a considerable argument for their use in skilled hands. If, however, there are such difficulties in rendering the inner bore of metallic catheters clean without the aid of heat, much more will there be with gum-elastic instruments. The inner surface is rough and irregular, and has none of the beautiful polish of the exterior, as will be seen by cutting such a catheter open. In private practice the writer always tries to make use of new catheters for every fresh patient, or to keep the same catheters for the same patient. Even this is difficult, and in hospital practice it will be found next to impossible. Some plan, then, by which the catheter can be purified, or, if not absolutely purified, rendered innocuous to the patient next succeeding, is very important to obtain. Such plan the writer has carried out lately by dipping the catheter into a thin solution of spirit polish, rendered flexible and unlikely to crack by the addition of a small quantity of castor oil (10 drops to a fluid ounce of the polish). After such dipping, the catheter has to be drained and hung up to dry, all touching being avoided until it is absolutely dry. This process renews the polish on the exterior, and if there be any foreign material in the interior, it varnishes it down, so that it no longer floats about freely when the catheter is used—to say nothing of the antiseptic effect of the rectified spirit upon it during the soaking and drying processes. Of course, this process sooner or later chokes up the bore and eye of any catheter, the smaller ones espe-

cially, but it will be found that it prolongs the life of a catheter very much, and it also offers a mode of proceeding by which one is not afraid to make use of a catheter about which it is doubtful whether it has been used before or not. It will be of especial service to country practitioners, whose opportunities of getting new catheters are very limited, and who yet do not wish to keep a large stock of such perishable articles.

Sponge Preparation and Cleansing

The question whether sponges are reliable articles, and should be used for operations, has for many years been a moot point amongst those practising antiseptic surgery. By many, sponges have been discarded altogether, as involving too much risk of carrying material from one patient to another. These surgeons use lint or wads of cotton-wool, which are thrown away after the operation. Since the manufacture of the cheap cotton-wool artificial sponges (each containing a glass globule with eucalyptol in its interior, which is to be crushed at the time of use), the performance of even large operations has become very possible by their use. And it may be laid down as a general rule that these artificial sponges should be used in all foul cases, if possible. But even these are very imperfect substitutes, and, in fact, true sponges are articles which will not be lightly given up by those who know their valuable qualities if in any way they can be made reliable. Other surgeons will only use new sponges; this, however, is a very expensive proceeding, almost impossible for hospital practice, and it distinctly introduces a new risk—in the imperfect freeing of the new sponge from all the sand and other foreign material which commercial sponges contain. It is possible to do this effectually where only a small number of new sponges have to be prepared, but it would be practically impossible where a very large number are used, as would be the case if new sponges had to be prepared for every operation. As a matter of fact, the writer believes from long experience that sponges may be so prepared and cleansed after each operation that they can be used with perfect safety from one patient to another. The first cleansing of a commercial sponge from sand, &c., consists in first shaking and beating the sand out dry, then soaking and squeezing in many successive waters. This will probably take days or weeks to perform. It is very desirable that it should be thoroughly done, for, in addition to the sand, new sponges generally contain very minute transparent spines, which run into the skin and are very painful and difficult to remove, as all who have cleaned new sponges will know to their cost. The irritant effect of these spines upon a wound may be well imagined by those who have experienced their effect on the skin.[1] When free from the sand, a new sponge may be softened and bleached by first soaking in fairly strong solution of permanganate of potassium until the sponge assumes a deep brown tint, and then passing it quickly through a solution of sulphurous acid (the pharmacopœial preparation mixed with an equal bulk of water). This process not only whitens and softens, but detaches and dissolves hard particles remaining, and after again washing freely in water the sponge is ready for use.

Another plan, recommended by Borham, and adopted by Greig Smith (' Abdominal Surgery,' 4th edit., p. 64), consists in soaking the sponge, after treatment with the potassium permanganate, in a solution of sodium hypo-

[1] The freeing of imported sponges from sand, &c., is now generally done by machinery on a very large scale. The purchase of the already cleaned sponges saves much time and labour, but even in these some sand is left behind, and care should be taken to free them from this remnant as carefully as possible. Bleached sponges can now also be purchased, of course at considerably enhanced cost.

sulphite (half a pound to a gallon of water). To this solution, after soaking the sponge for a time, about four ounces of oxalic acid are added. A chemical action follows, sodium oxalate, sulphurous acid, and free sulphur resulting. The sponge becomes rapidly bleached, and any free fibrin contained in its meshes is dissolved out. The sulphur set free requires a good deal of washing to get rid of it, and hence this process takes longer than that already advised. On the other hand, a small quantity of free sulphur left imbedded in the sponge probably slowly oxidises, and thus may tend to keep it sweet.

When a sponge has been *saturated with blood* during an operation it should first be cleaned by soaking and squeezing in frequently renewed *cold* water. (Very hot water coagulates the albumen of the blood and makes the sponge much more difficult to clean. It also damages the texture of a sponge, and boiling a sponge so shrinks and contracts it that it is scarcely fit for use afterwards. Hence the method of heat is inapplicable in the disinfecting of a sponge.) When free from blood and coagulum, as far as possible, it should be put to soak in carbolic lotion (1 in 40) for twelve to twenty hours; then again washed freely in cold water before being put aside for use. Every sponge before a fresh operation is put to soak in 1 in 40 carbolic lotion. This method is the one almost universally in use at Guy's Hospital, and gives satisfactory results. If a sponge has been used for a very fœtid discharge, it should be either thrown away or put to soak in some of the bleaching solution of sulphurous acid for a quarter of an hour before soaking in the carbolic liquid. It is curious that sulphurous acid has very little bleaching power upon a sponge which has once been soaked in carbolic solution, though it readily bleaches before this is done. The writer has thus gone into the question of sponge treatment because he believes it to be one of very considerable importance. For a long time he was doubtful whether any cleansing process was sufficient for a sponge once saturated with blood, but long experience and careful watching of the cases where sponges so treated have been used have convinced him that, if fairly done, they can be relied on. The results of abdominal surgery with such sponges have perhaps done more to convince him of the efficiency of the process than anything. He has used many other methods also. A dilute solution of a caustic alkali has perhaps been the favourite; it tends to dissolve the fibrinous coagulum, but it also damages the texture of the sponge if frequently used; and he has come to the conclusion that it is not necessary.

Cooking Arrangements

The ward kitchen should always be separated from the ward, and separate ventilation should be provided for it. The old custom of cooking in the ward by nurses or helpers can only be described by the word 'nasty.' It is probably not so injurious as many other things about a ward, but the mingling of the fumes of the cooking with the air of the ward destroys its freshness and cannot conduce to the patients' appetites. Moreover, it takes off the attention of the nurses from their proper duty, viz., nursing.

Isolation Wards

These are absolute necessities, both for medical and surgical cases, in all hospitals: in the latter more especially, for erysipelas and very foul cases; in the former, when there is an epidemic outbreak of zymotic disease, such as scarlatina, measles, small-pox, typhus, &c.

The avoidance of the undue herding together of the fever cases causes the dilution of the poison and contributes in a marked degree to their recovery. It is always difficult to prove this from statistics, the number of cases dealt with even in the large wards at Guy's Hospital being but small. But it is supported by much that is observed in private practice in infectious cases, and also by what has been observed in some of the fever hospitals. In the latter, the late Dr. Mahomed (who as physician to the Fever Hospital at Islington had a large amount of experience in such cases) is the writer's authority for saying that after every time of purifying, white-liming, and re-painting the wards, the patients with scarlatina first received into them did better than those received into wards not so purified; that the walls, &c. after a time became so saturated with the poisonous emanations that even fresh scarlatinal cases, presenting a mild type when first received, were very liable to severe throat troubles, glandular abscesses, and sloughings, &c., when they were received into wards at all *stale*. And this is in accordance with the writer's own experience in private practice. He has on two or three occasions seen an epidemic of scarlatina run through a large family or school of children. These children have been placed in two or three rooms in the top of the house, case after case as they occurred. The first case has been of a mild type and has done well. The succeeding cases have presented symptoms of increasing intensity, and in the last case or two he has been called in to do various surgical operations on their throats for sloughing glands, and phagedenic ulcerations of the worst possible type. He has always attributed this to the intensification of the poison in the rooms set apart for the patients.[1]

In the case of scarlatina, measles, and small-pox it may be conceded that isolation rooms or wards are absolutely necessary for the safety of the rest of the patients, but great care should be taken in the frequent purification and disinfection of such wards. In the case of typhus probably the same is true, though, with due care as regards number, cases of typhus in former epidemics have been placed and treated successfully, without spread of the malady, in the large wards at Guy's amongst the other patients. In the case of typhoid and diphtheria a certain number of such cases are still admitted into the general medical wards with favourable results. As regards typhoid, the spread of the malady amongst surrounding patients is almost unknown, if the before-named proportion of cases is duly maintained. It is very many years since an epidemic of typhoid has occurred in a Guy's ward—and when that took place it was due to accidental overcrowding of typhoid cases into one ward. As regards diphtheria, the risk of the spread of the disease is greater, but more amongst those nursing the case than amongst the ordinary patients, though even the latter is not unknown.

Although an isolation ward should be attached to every general hospital, it is not desirable that this ward should be made use of for the treatment of

[1] The writer would note here the very great improvement in the treatment of such cases by the extended use of aërial disinfectants. The old method of a sheet saturated with carbolic solution and suspended in the chamber had a certain value, no doubt, but it was altogether insufficient. In the method of vapourising carbolic or creosotic antiseptic compounds by heat, there is a very great improvement. Many instruments for this purpose are now sold. The little cresolene lamp may be cited as an instance. This is a very small petroleum lamp with a porcelain cup fixed over it, in which the cresolene is placed. The cresolene only evaporates very slowly, and condenses on everything in the chamber, so that in a room in which it has been burning for some hours everything—curtains, walls, bed, &c.—smells more or less of the material. Efficient antiseptics used in this way cannot but have a considerable value in diminishing the virulence of the septic poison.

an infectious fever during its entire course, but only for the separation of the case from other patients while the diagnosis remains doubtful. When the case has fully declared itself, it should be removed, if possible, to a hospital for such cases entirely separated from general cases. In London this is carried out by the removal of such cases to the hospitals of the Metropolitan Asylums Board.

The *disinfection of an isolation ward* is best accomplished by burning sulphur in it, and keeping the room as tightly closed as possible for twenty-four hours afterwards. The fireplace should be closed by temporarily pasting paper over it, and the crevices of the windows and doors as far as possible by sand-bags. The amount of sulphur burnt should vary with the infectiousness of the case or cases which have been previously in it. A good rule is to burn not less than one pound to every 2,000 cubic feet of space. The sulphurous acid gas so produced impregnates everything in the apartment, and acts in itself as a most potent germ-destroyer. In addition it oxidises slowly in contact with the atmosphere, and thus becomes converted into sulphuric acid, which remains very persistently about everything, and this acts still further as a germicide. At the end of twenty-four hours the ward should be thoroughly aired, and walls and floor washed with solution of carbolic acid (about 1 to 40). Fresh white-liming the ceiling is a good adjunct, but it cannot be done after every case, and it is not necessary. At the London Fever Hospital the small separate rooms used for private patients and doubtful cases are disinfected after every patient, but the larger wards can only be done periodically. The reason, however, for disinfection of the small rooms after every patient is that, when patients are first taken in, the diagnosis is sometimes doubtful, and it would not be right to place a patient, perhaps not suffering from any infectious disease at all, in a ward which had been just occupied, say, by a scarlatina or measles case, without in the first place thoroughly disinfecting it. The same rule should be applied to all isolation wards in general hospitals. It has long been in use in those at Guy's Hospital with the most beneficial results.

Results.

With the greatly increased care given to the hygienic condition of the wards in our hospitals a most remarkable improvement has followed in the mortality statistics of operations. Erysipelas and pyæmia have almost completely disappeared as endemic affections in our hospitals. Indeed, if a case of blood poisoning is seen in a ward, it may be almost certainly assumed that it has either been admitted as such from outside the hospital, or that the case has been of such a nature as to lead to very widespread infection of poisonous material, such as cannot be entirely disinfected and destroyed. As instance of the former, the writer may mention the cases of acute necrosis—examples of which are always to be found in surgical wards. As instance of the latter, the cases in which London mud and dirt have been very deeply ingrained into the cutaneous and deeper structures, in those accidents in which patients have been dragged for a distance along the pavement or over granite setts, thereby producing a very deep inoculation of the foulest dirt in existence, viz., the various excreta which constitute the mud and dust of the streets of our large towns. Such inoculations often occur over areas of tissue so extensive, that it is practically impossible to remove or completely destroy the infective material. The difficulty is rendered the greater, because, in spite of the foulness of the material ingrained into the tissues, many of these cases show such power of resistance to the poison

that they ultimately do well. Nevertheless, in such cases the risk of septicæmia and tetanus is considerable. Thus in a case which was admitted into the writer's ward at Guy's Hospital, while away for his summer holiday some years ago, the patient had fallen into a dustbin, producing a compound fracture of both his legs. The bones protruded and were caked with dust. They were very carefully cleaned and disinfected before reduction, but it was recognised at the time that perfect cleansing and disinfection were impossible. On his return the writer found the boy suffering both from tetanus and from marked signs of pyæmia. He amputated the worse leg, but naturally failed to save the life of the patient. The *post-mortem* examination showed abscesses in the lungs and commencing suppurations in the joints. Instances such as this might be multiplied, but it is evident that their existence does not prove anything against the healthiness of surgical wards. It is only when cases of blood poisoning arise *de novo* within the ward, in cases of operation in which the wound was originally sweet, and ought to have been kept so, that any fear should arise as regards the hygienic surroundings.

There can be no doubt that the main cause of the improved results in all surgical wards of late years is almost entirely due to the adoption of the plan of treating wounds advocated by Sir Joseph Lister. In Guy's Hospital, for example, the condition of the surgical wards, as regards ventilation, heating, and general sanitation, has not been very materially altered from what it was twenty years ago. And yet by the simple adoption of this mode of treatment of wounds, erysipelas, pyæmia, and blood poisoning, as just said, have been almost abolished from the wards, and operations of the most serious kind are now done safely, which formerly would almost certainly have terminated fatally. This improved state of the wards reacts also in the improved health of the resident medical staff. Twenty years ago it was exceedingly rare for the house surgeon of the period to pass through his four-months term of office without being laid up once or more, often by an attack of what was called 'surgical sore throat'—a form of septic absorption due to foul smells arising from surgical wounds and dressings. *Now* the occurrence of surgical sore throat in the resident staff is very rare. Again, the writer will have to show later on that in quite another department of medicine, viz., midwifery, the great improvement in the mortality of the General Lying-in Hospital took place—not after structural alterations, and improved hygienic appliances about the hospital—but after the use of corrosive sublimate solution as a germicide, for injections, for the nurses' hands, and for disinfecting all instruments. The writer would not wish for one instant to undervalue the importance of all hygienic arrangements in hospital and ward construction, &c., as well as the hygienic ordering of a ward; but it is important that the relative value of these factors should not be lost sight of, and the fact remains that to the recognition of the truth of these principles must be attributed the great surgical triumphs of the age.

As an example of the condition of things in surgical wards prior to the advent of Listerism (a condition which sounds almost incredible now, after the lapse of only twenty years), the writer may mention an incident which occurred to him when first appointed (in 1870) on the surgical staff of Guy's Hospital. One of his early operations was an amputation through the thigh for a compound smash of the leg. The Sister of the ward (who had been forty years in the service of the hospital) shook her head after the operation and prophesied the death of the patient, remarking that '*these cases never recovered.*' In that case she proved right, though the statement itself was no doubt an exaggeration. Still it shows the general impression which the results of these thigh amputations had left in her mind. At the present

time no Sister of any experience in Guy's Hospital could repeat such a statement. Indeed, thigh amputations in the lower thigh for disease (excluding such cases as senile gangrene, &c.) have come to be regarded as among the safest of major operations, and this is due mainly to the abolition of pyæmia and septicæmia in the wards, from attention to all these various hygienic details.

The statistics of amputation of the thigh as given in one of the older surgery books offer striking testimony to the difference in the condition of hospitals now as compared with thirty years ago. Thus, in Mr. Erichsen's 'Surgery' (4th edition, 1864), p. 31, a table is given of amputations of the thigh for injury by various operations, in which the mortality is, for primary amputations, about 74 per cent.; for secondary amputations, about 61 per cent. In Mr. Dent's recent paper on the mortality in 400 cases of amputations at St. George's Hospital, performed since 1874 (*vide* 'Med.-Chir. Trans.' for 1890, vol. lxxiii.) a table is given (p. 369) of thirty-five cases of primary and secondary amputations for injury, with a mortality of 62 per cent. At first sight this does not seem any very marked improvement on the preceding, but when it is known that this table includes *double amputations*, which were all fatal, and that part of the period referred to includes cases in which antiseptic surgery was either not practised at all or only very imperfectly attended to, it will be seen that the mortality represents a very considerable improvement on what has gone before. The same relative improvement may be noticed by comparing the amputations through the thigh (performed for disease) in the same hospital at different periods. At this hospital careful statistics of the results of all the amputations have been kept since 1852. This period may be divided into two[1] (corresponding with the dates of Mr. Holmes' and Mr. Dent's papers respectively on the subject). The first period is from 1852 to 1874; the second from 1874 to 1888. During the first period, antiseptic surgery was mostly not practised at all, though towards the end of the time very imperfect attempts at its introduction were made. During the second period, the principles of antiseptic surgery were much more fully understood and practised, though even this includes some cases in the earlier years not so treated. In the first period, the mortality of amputation of the thigh (for disease) amounts to about 29 per cent.; in the last period, to 16·9 per cent. The same thing is to be observed in the amputations of the leg for disease. In the earlier period 110 amputations gave a mortality percentage of 24·5; in the latter period, in fifty-eight amputations, of 10·3. Again, in the amputation of the arm for accident, a mortality of about 38 per cent.; in the latter one, of 20 per cent. In the same amputation for disease, a mortality in the first period of about 14 per cent., against a mortality of 0 per cent. in the second (10 amputations). Similar examples (obtained by comparing the results given in the same papers) might be multiplied. The writer may, however, be permitted to cite the results (*loc. cit.*, page 363), in which Mr. Dent compares all the amputations included together, but divided into those performed at different ages. After giving a table (to which the writer would refer those interested in the subject), he says:—'The most noticeable contrast will be observed in the third series of amputations, between the ages of twenty and fifty. The mortality between the ages of twenty and thirty, which in the first series amounted to 18·9 per cent., and in the second series to 34·7 per cent., in the third has fallen to 14·7 per cent.

[1] In the paper referred to, Mr. Dent divides the periods into *three*, but for my purpose this needlessly complicates and lengthens the subject.

Between the ages of thirty and forty, the figures are still more striking, for the mortality as shown in Table I., which in the first series was 39·6 per cent., and in the second 40·4 per cent., has in the third series fallen to 14·2 per cent. Between the ages of forty and fifty, much the same results will be observed. The improvement shown in the third series is chiefly due to the diminished mortality in these three divisions.'

Still more striking becomes the individual experience of a surgeon practising antiseptic surgery in a ward where all the other cases are treated on the same principles. Selecting amputations of the thigh as a test case, because the mortality in these is more striking than in the other amputations, the writer has looked out all the cases in the hospital case-book for the years 1888–89–90 which have been operated on by him. He finds they amount to twelve, all from disease, with only one death, and this was in an old man, aged seventy-three, in whom the amputation had been done for senile gangrene with serious kidney and arterial disease. This gives a mortality of 8·4 per cent. It is true that the number of amputations during these three years is not large,[1] but the writer is very strongly of opinion that if the statistics of previous years could be examined, the mortality would be found not higher than this. During the three years, there have been also two cases of amputation at the hip-joint, which have both recovered.

Allusion has been made to the great diminution in the number of erysipelas cases in the surgical wards of Guy's Hospital since the introduction of Listerism. Dr. Steele has been kind enough to obtain for the writer the total number of cases admitted from the hospital wards into the isolation wards (the so-called 'erysipelas wards') during the last four years. In round numbers they amount to about twelve a year. But it must be added at once that very few of these are erysipelas or blood-poisoning cases *originating in the ward.* They are mostly foul cases (ulcers, gangrene, &c.), admitted as such, and sent up at first into the general wards, and thence transferred at the surgeon's first visit to the 'erysipelas ward.' On account of the limited accommodation in this ward, it is a rule at Guy's Hospital that no case is to be admitted to it from outside, except under circumstances of great urgency, and with the consent of the medical superintendent, but that the beds are to be reserved for cases occurring in the hospital. When the ward, therefore, is partly empty, the temptation to the resident staff to send an urgent foul case into the general ward, or even one which is already showing signs of blood poisoning, so that it may be passed into the erysipelas ward, is very strong, and this accounts for the number of such cases admitted. No record has been kept in the 'erysipelas ward' (and it would be very difficult for any Sister to do so) of the numbers of the two classes of cases, viz., those originating *de novo* in the ward, and those admitted into the general ward as foul cases, merely for the sake of being passed through by the surgeon in the course of the first few days. So that for information on this head the writer can only appeal to the individual experience of his own ward. In Dr. Steele's return, he finds that during the whole four years there were no cases admitted from Naaman ward (the male ward), that there was one case admitted from Charity ward (the female ward), in eighteen months, and one[2] from Accident ward in two and a half years. *Neither of these cases* were cases originating in the wards, but came from outside, and

[1] The writer is not able to give the statistics of these amputations in the years previous to 1888, owing to a technical defect in the indexing of the hospital case-book, which has since been remedied.

[2] In neither of these wards is the return sufficiently full to enable the writer to state the number in the full period of four years.

passed through the ward in the manner above described. As explaining the total absence of cases from Naaman ward, it may be mentioned that the beds are in great request, and nearly always promptly filled by a fresh case from the country or elsewhere directly one falls vacant, so that the resident staff have comparatively small chance of making use of these beds in the manner before mentioned.

Such a fact as this justifies the statement that Listerism has nearly, if not quite, 'abolished erysipelas from our wards.'

Looking at the matter from quite another standpoint, the improved hygienic condition of the wards of large hospitals shows itself in the diminished mortality of the large lying-in hospitals. It is not very easy to obtain any exact returns of mortality in these hospitals in the years before the introduction of antiseptic midwifery. In many places it was often so high that no returns were published, and it is probable that none were even kept. But it may almost certainly be assumed that we are putting it at a very moderate estimate in stating that the deaths were 30 per 1,000, almost entirely from septic causes, in the pre-antiseptic years. Very often it was much higher than this. Thus Dr. Cullingworth states in a lecture delivered in St. Thomas's Hospital (and reported in the 'British Medical Journal' for October 6, 1888, p. 743) that at the Paris Maternité the mortality from 1858 to 1869 amounted to 93 per 1,000. In the New York Maternity Hospital the deaths amounted to 60·6 per 1,000 from sepsis during 1883, and in the Boston Lying-in Hospital to 55·5 and 45·8 per 1,000 in the years 1882 and 1883 respectively. This was just before the introduction of antiseptics into midwifery, and in both the last hospitals the change in the mortality is most striking. Thus in the New York Maternity Hospital the mortality fell in 1884 to 5·9 per 1,000, and in 1885 to 1·8. In the Boston Lying-in Hospital the mortality fell in 1884 to 16 per 1,000, in 1885 to 6·4, and in 1886 there were no deaths from sepsis.

Amongst the English lying-in hospitals the results at the General Lying-in Hospital are best known, and most striking. To quote a table from the same paper by Dr. Cullingworth :—

Table showing mortality at General Lying-in Hospital from 1833 *to* 1887.

Date	Deliveries	Deaths	Average mortality per 1,000
1833 to 1860	5,833	180	30·8
1861 to 1877	3,773	64	17
1880 to 1887	2,585	16	6

Thus the mortality has fallen from 17 to about 6 per 1,000 in the last septennial period. Even this does not represent the full advantage obtained. Since 1887 puerperal fever has almost entirely disappeared. 'Only one death has taken place from this cause during the last three years, and it has come to be regarded as quite an unusual event for a patient's temperature during convalescence to exceed 100° Fahr.'

On the other hand, it is not possible in this and many other lying-in hospitals to obtain full and accurate statistics of the exact mortality in the pre-antiseptic days. 'Until the year 1887 this hospital was scarcely ever free from puerperal fever, and the mortality, always high, occasionally became fearful. In 1838, of seventy-one women delivered, nineteen died; in 1861, fourteen died out of one hundred and ninety-five ; and in 1887, nine out of sixty-three. On several occasions the hospital had to be closed for

long periods, and thousands of pounds were spent on the sanitary improvement of the building' (Cullingworth, *loc. cit.*).

These greatly improved results have been obtained partly by the use of corrosive sublimate lotions (1 to 1,000) for the hands, instruments, such as catheters, &c., and corrosive sublimate lubricants, e.g., mercuric chloride one part dissolved in 1,000 parts of glycerine; partly by attention to most of the hygienic details enforced in the previous parts of this paper. Thus one of the working rules is to allow only a certain number of confinements to take place in a ward, after disinfection and cleansing; thus giving practical application to the remark which the writer has already quoted from the late Dr. Mahomed, that in his experience at the Fever Hospital the mortality from scarlatina was always less in those wards which had recently been re-painted and cleansed.

The details respecting the successful working of the General Lying-in Hospital have been recently very fully given in a paper read before the Obstetrical Society by Dr. R. Boxall, on 'Fever in Childbed' (*vide* 'Obst. Trans.,' 1890, vol. xxxii., pp. 264–270). As the change in the mortality and amount of fever in this hospital is so very remarkable, and as we possess all the main facts during the last seven years, it will be worth while to give the mode of successful working, as stated in Dr. Boxall's paper, the more so as they form an effective commentary on much that has been already written in this article.

The General Lying-in Hospital is a small one, containing only twenty-four beds. It is divided into small wards, containing only three and four beds each. Thus 'most of the lying-in wards have three beds each, one rather larger than the rest has four, the convalescent ward four beds, and the isolation ward one bed.' A clear space of 2,000 cubic feet is allowed for each bed. There is a special 'labour ward' on each floor for the reception of one or if occasion require of two patients.

It should be said that no structural alterations have been made in the hospital during the last seven years, so that the altered mortality can only be attributed to the improved method of working the hospital. The hospital was founded in 1765, occupies a site in a densely populated part of Lambeth called 'The Marsh.' The structural alterations and sanitary improvements, already referred to, were all made prior to the last septennial period.

The wards and ceilings of the wards are all painted. The floors are partly polished, but the old deal floors were found unsuitable for this purpose, so that with the exception of one ward recently laid with teak, the old mode of cleansing has been maintained.

Closets and slop-sinks are provided on each floor, and are built out in a turret so constructed as to include a passage shut off from the corridor by doors, and ventilated by windows on each side. All the drains are outside the building, and, together with the soil-pipes, are freely ventilated. The drains are disconnected from the main sewer, and are flushed automatically every twelve hours.

The ventilation and warming of the wards are practically done by means of open fireplaces and open windows. Hot-air pipes were laid at great expense throughout the hospital some years ago, and an outlet ventilating shaft was provided for each ward. These, however, worked so inefficiently that for the last ten years they have been discarded. Fires are kept constantly burning in the open grates, and all the windows are kept open at the top at least six inches, and the inside venetian blinds are turned so as to direct the incoming current of air upwards. Tobin's tubes are used in one ward, where the windows are all on one side, and the ventilation is reinforced throughout by

inlet ventilators near the floor and Sherringham valves at the upper part of the outer wall.

As regards the important elements of clothing and bedding, each lying-in ward and delivery room is provided with its own set of instruments and utensils. Hair mattresses are used. Both infants and mothers are provided with special clothing during their stay in hospital, and the clothing which the mothers wore on entrance is mostly taken away by the friends. This was necessitated by an outbreak of scarlatina in the hospital, brought in from outside, some six years ago. All laundry work is contracted for outside the hospital, and the clothes and bedding are despatched there three times a week, without being previously disinfected or otherwise treated. But when returned, the clothes are put into a Fraser stove and the temperature raised to 250° Fahr.—'more with a view to airing it efficiently than of effectually destroying infection.' Up to three years ago the mattresses used also to be stoved, but as it was found impossible to keep them in the heat for a sufficient time to destroy all possible infection without injuring the fabric, this was discontinued. 'At the same time each mattress was numbered, and a register was instituted of each patient for whom it was used, so that any defect might be at once traced. Any mattress which has been used for a case likely to infect it is, however, at once sent away in order to undergo disinfection by superheated steam.'

'The labour wards are fumigated and washed after every six deliveries. The lying-in wards are disinfected after the beds have been once occupied. When a ward is vacated by a batch of patients, the bed linen is removed, but the mattresses and blankets are suffered to remain suspended during the process of fumigation and removed afterwards. Five pounds of sulphur are burnt in the lying-in, and two pounds in the labour wards. The ceiling, walls, floor, and bedsteads, &c., are then washed down with carbolic solution, 1 in 20. During the last three years, the fumigation has been performed between each batch of patients, the additional washing between every other batch. Before that, it was the practice to fumigate, to wash, and then to fumigate again, not between every batch, but between every other batch of patients (*loc. cit.*, p. 267).

Nurses in attendance on cases outside the hospital are not permitted to attend those in the hospital. While on duty within the hospital both midwives and nurses are required to dress in washing material. Separate day-nurses are provided for each ward, and a separate night-nurse for each floor. The nurses assist at the labour cases in rotation.

The only patients considered unsuitable for admission are those with foul wounds, which would entail risk to other patients. Patients are admitted by letter; they are usually 'more or less advanced in labour on admission, and are conducted at once to the labour ward, where they are dressed in hospital clothes, and in all cases, where time will allow, the passages are irrigated with three quarts of antiseptic solution before delivery, the douche being repeated if the labour be prolonged. One or more such vaginal douches at a temperature of 115° Fahr. are invariably given after labour is complete, and any considerable tears about the vulva are immediately closed by suture.' Two hours after delivery the patient is removed on a trolley to the lying-in ward. A slop diet only is allowed until the bowels have been freely moved, but fish is generally allowed on the third day, and afterwards meat. A liberal supply of milk is allowed, but beer has been discontinued since 1884, as it was found to make the patients feverish and uncomfortable for some hours after having taken it. The patient's friends are allowed to visit her on two

afternoons in the week, after the fifth day, and the patient is allowed to get up about the ninth day.

Antiseptics employed.—It has been already said that the great improvement in the sanitary condition of the hospital dates from the employment of mercuric chloride (corrosive sublimate) in the form of injections, washes, and lubricants for the hands and instruments. Various other antiseptics have, however, been used. Permanganate of potassium and carbolic acid were the principal ones immediately prior to the advent of the mercuric chloride, and they were attended with a very considerable measure of success. But these two antiseptics are naturally antagonistic and destructive of each other, so that their use together probably diminished the activity of both. Moreover, they are both rather irritating to the mucous membranes, if used frequently as injections, or if used for a long period. The same must also be said as regards mercuric chloride, and cases have occurred of mercurial poisoning from its use in the stronger forms. Probably from this arises the fact that the solution is used frequently of strengths less than 1 to 1,000. Indeed, the stronger form is only employed as a first injection, or when any special circumstances arise calling for its use. The more frequent strength employed afterwards is 1 to 2,000, and in some cases even as low as 1 to 4,000. As corroboration of its irritant character on mucous membranes, the writer has seen in surgical cases in general hospitals the employment of a strength of 1 to 1,000 on the mucous membrane of the mouth, rectum, or vagina, for three or four days consecutively, cause great irritation and inflammation of those membranes, so that he uses it only very sparingly for such operations. On the other hand, it appears to have comparatively little irritant effect on freshly cut tissues, so that it is more suitable for wounds than for use where the mucous membranes are concerned.

Partly on account of this irritant action of mercuric chloride, the medical staff of the General Lying-in Hospital sought for some other antiseptic, which should not have the same irritant quality, while possessing equal antiseptic value. With this view a systematic trial was given to salufer (silico-fluoride of sodium), 1 to 500 solutions, as a part substitute for the mercuric chloride. But it was found that during the period of trial the number of cases of pyrexia during the puerperium rose considerably, and the average temperatures were much higher than under the treatment by mercuric chloride, so that it was abandoned, and the use of the latter was resumed. And it may be added that this is the antiseptic which is still almost entirely used, and that in spite of the occasional occurrence of mercurial poisoning, the risks of sepsis are so much greater than those of mercurial poisoning that the continued use of the mercuric chloride is more than justified.

It must be allowed that the patients admitted into a lying-in hospital require peculiarly stringent treatment as regards antiseptic precautions. From the maladies too often prevalent amongst them, such as gonorrhœa, syphilis, and various forms of soft sore, to say nothing of their liability to come from infected homes where scarlatina, measles, or other zymotic affections are raging, such hospitals are more liable to outbreaks of puerperal fever than other general hospitals are to erysipelas, pyæmia, or other form of blood-poisoning. The mucous membranes of the female during the puerperium are peculiarly subject to the absorption of such poisons. It may be, therefore, that some of the precautions necessary at such hospitals may not be so necessary at general hospitals. Still in many respects the precautions found absolutely necessary at the general lying-in hospital might probably be imitated advantageously elsewhere. Though many of the large

infectious disease hospitals of the Asylums Board, and others elsewhere, are most ably managed, the writer thinks that there is room for improvement in most of them in the future. The herding together of large numbers of infectious cases must always be looked upon with suspicion from a hygienic point of view. In some respects such hospitals might take a lesson from the conditions of healthy working found essential in a lying-in hospital. The writer would indicate two such points :—viz. (1) the treating of infectious cases in small wards, containing each three or four patients, where they would pass through the similar stages of the fever at the same time ; (2) the frequent cleansing and disinfection of such small wards. This should be done, in his opinion, after each batch of patients had vacated the ward, and it would be rendered possible by the smaller size of the ward. Such disinfection would probably contribute to the progress of the fever case itself, and would render less likely and less frequent the spread of the fever amongst the medical attendants and nurses.

THE DISPOSAL OF REFUSE

BY

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THE DISPOSAL OF REFUSE

DEFINITION

The refuse of a community includes the dry refuse of the house (ashes, dust, and refuse food), the fæces and urine of men and animals (the excretal refuse), and the waste waters from cooking and washing in houses. All these matters are the waste products of the individual house or establishment; but in all towns the municipal authority must make arrangements for the collection, removal, and disposal of the liquid and solid waste substances from stables, cowsheds, and slaughter-houses, the sweepings of the streets and markets, and the waste waters from works and factories, in addition to the more strictly domestic waste matters.

Methods of Removal.—Some of this refuse material being in a more or less solid or dry condition may be removed by mechanical labour; and in many towns in this country the municipal scavenging department undertakes the collection and removal of the dung from stables, the ashes, dust, and food scraps from houses, and the sweepings from the streets and markets. In some towns human fæces and a certain amount of urine are also removed by this method, after being deposited in dry closets or privies. The system is still largely in use in the towns of the midland and northern counties. Necessarily scavenging operations, as usually conducted, fail to deal with any but the more or less solid refuse; consequently the house waste waters, the rain water from roofs, paved yards, and streets, the liquid drainage from stables, and the waste liquors from manufactories, must be carried away from the houses in drains, and from the town in sewers; in other places the excretal matters are collected in underground cesspools, which are emptied from time to time. These are known as the conservancy systems of excretal removal, the refuse matters being necessarily kept for a certain period in or near to the house.

Most towns in this country have long been provided with drains and sewers for carrying off the liquid wastes, and the rain water which falls over the surface covered by streets and buildings; and it soon came to be recognised that there was a distinct advantage in removing the solid human excreta as well in this manner. For by carrying these substances away in drains and sewers, the most offensive and dangerous portions of the human refuse matters were removed at once from the neighbourhood of houses, and the necessity for retention on the house premises, which is the very essence of all conservancy systems, was thereby avoided. This system of removal of excreta by water carriage from the neighbourhood of houses and towns is, where circumstances are favourable to its execution, the one best suited to our national habits, and, sanitarily considered, is far preferable to any conservancy system.

REMOVAL OF DUST, ASHES, AND REFUSE FOOD

Arrangements must be made by the sanitary authority for the removal of household dust, ashes and cinders from fires, scraps of waste food, and other refuse matters. Inasmuch as these substances can only be removed at intervals from the houses where they accumulate, it is important that they should be so stored and kept as to remain inoffensive during their period of retention on the premises. The dust and ashes, being in great part mineral substances, are not likely to give rise to any nuisance, but the organic matters contained in the scraps of refuse food will ferment, putrefy, and cause serious nuisance unless suitable precautions are taken. Obviously the first indication is to limit, as far as possible, the quantity of these waste organic substances that must be stored on the premises to await removal by the scavengers. In well-organised households all those waste matters that can be destroyed by heat may be burnt in the kitchen fire. Such as are indestructible must be placed with the ashes and dust in the dustbin.

Until quite recently, dustbins were large receptacles constructed of brickwork, backing upon a wall in the yard, or against the side of the house, with an opening above protected by a wooden cover, and a door at the side for removal of the contents. The cover being liable to removal, the contents of the dustbin were often exposed to rain; the water saturated with noxious organic substances penetrated into the ground or into the brick walls of the house, against which the dustbin was placed, and in summer the combination of heat and moisture caused rapid decomposition of the organic substances, with evolution of offensive and injurious gases.

These disadvantages of the old-fashioned brick dustbin have caused it to be largely replaced by small galvanised iron pails, which should be provided with a properly fitting metallic cover, in order to ensure dryness of the contents. If the contents are properly dry, fermentation and the production of offensive gases is avoided, even although the temperature of the air is high. The iron pails being non-absorbent, their walls are not saturated with foul organic substances as are the walls of brick dustbins; and being easily movable the pails may be placed in such a position as to cause least offence to the inmates of the house, and are easily carried by the scavengers to the dust cart, into which their contents are at once emptied. In several parishes of London the local authorities have now gratuitously provided every house with a galvanised iron pail to replace the brick or wooden dustbin, and the excellent sanitary results of this system more than counterbalance the initial expense.

As frequent a removal as possible of the dustbin contents is greatly to be desired. A daily removal is what should be aimed at; but this would involve considerable expense, and it is not usually found practicable to carry out more than a bi-weekly removal. In many places the dust carts only call nominally once a week, and in reality at many houses of the parish or district at even longer intervals. It is certainly to be recommended that during the summer months the removals should be effected twice as often as in winter.

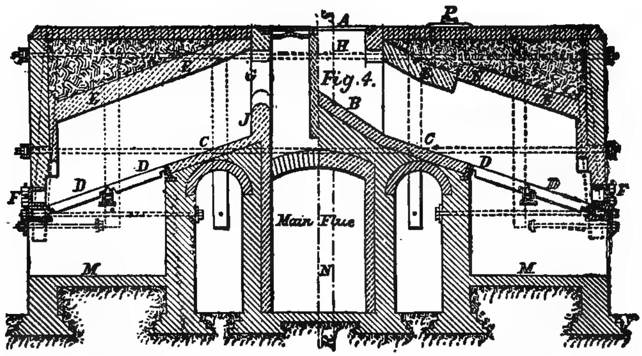
Specially constructed carts should be employed in the removal of dustbin refuse, and they should be provided with a cover, to prevent the diffusion into the air of the streets of particles of dust, which, if derived from a fever-stricken house, may be the means of scattering infection broadcast.

A list of the matters which may be placed in the pails or dustbins for collection should be issued by the local authority to every householder. This list should include cinders, ashes, potato peelings, cabbage leaves, and kitchen

refuse generally; but instructions should be given that, wherever possible, as in large houses with good kitchen ranges, kitchen refuse should be burnt. Trade and manufacturing refuse, refuse building materials, and garden sweepings and cuttings, should be excluded from the list of what the local authority is bound to collect.

It is the almost universal experience that the dust collection is far more efficiently performed when in the hands of the local authority, and worked by their own officials, than when let out to contractors. Dust is no longer a marketable product as it was some years ago; consequently it is no longer in the interest of the contractor to collect as much as possible each day, but rather, as he is now paid to do what he formerly paid for the privilege of doing, it is his interest to do as little as possible.

The ultimate disposal of the dustbin refuse is a matter for the serious consideration of local authorities. The old system still obtains at many places of carrying the refuse to a large sorting yard, often in close proximity to inhabited houses. Here men and women are employed in sorting the refuse and separating it into *breeze* (cinders and small particles of coal), *hard core* (bottles, bones, crockery, metal pots, and pans), and *soft core*



FROM "ENGINEERING," JANUARY 21ST, 1881.

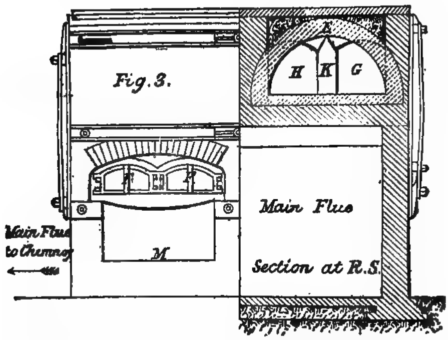
FIG. 162.—Fryer's Destructor furnace.

(animal and vegetable organic matters and textile substances). The breeze is sold to brickmakers; the hard core, or such parts of it as are worthless, is used in road making; and the soft core is mixed with fish offal, market sweepings, and horse droppings, and sent into the country to be sold as manure. The whole process of sorting is a noxious one, and degrading to the workpeople; and the foul odours given off during the process, and also from the heaps of refuse awaiting removal, whilst fermentation and decomposition are at work, often prove a most serious nuisance to the surrounding neighbourhood.

More recently it has been attempted to destroy the dustbin refuse in a Destructor furnace (see figs. 162 and 163). The proportion of cinders in the refuse is quite sufficient to ensure its complete combustion in a properly constructed furnace; but it has been found that a small amount of unburned or partly burned vapours, and a very fine dust, are liable to be carried off with the products of combustion, which escape into the air from the chimney. The unburned vapours impart to the escaping gases an offensive smell, which is perceptible to those living in the neighbourhood of the Destructor; and the dust is deposited on surrounding objects, and becomes also a subject of complaint. To ensure the complete combustion of the vapours and dust, a

Cremator furnace may be introduced at the foot of the chimney through which all the smoke from the Destructor furnace must pass. In this cremator unburned vapours and solid particles are completely burned up before they can enter the chimney flue.

At Bradford a fume cremator of this description (Jones's patent) has been introduced into the Destructor.[1] The gases from the Destructor furnace are made to pass over a coke fire on a grate, in a furnace covered in by a firebrick arch. The coke is fed in by openings at the top, and the fire is stoked through doors in the ordinary way. In this furnace are a series of firebrick arches or projections, called bafflers, which ensure that the gases shall not only be exposed to a great heat, but that they shall be exposed for a sufficiently long time. In the Bradford Destructor steam injections (Horsfall's method) are used to increase the draught in the furnace of the Destructor. A jet of steam under considerable pressure is forced underneath the fire-bars by means of a funnel attached to steam pipes leading from a boiler, which is itself heated by the combustion of the refuse. The steam jet causes a great inrush of air, thereby increasing the draught in the furnace and causing a more complete combustion of the refuse. After leaving the cremator the gases are carried under the boilers and finally into the chimney, which is 180 feet in height.



FROM "ENGINEERING," JANUARY 21ST, 1881.

FIG. 163.—Fryer's Destructor furnace.

Jones's Fume Cremator is in use for the Destructor furnace at Ealing. Besides consuming the dustbin refuse, this Destructor burns up the sludge produced by chemical treatment of the sewage of the town. The sewage sludge—which is an unsaleable product—after losing about 25 per cent. of its moisture by draining, is mixed with about two-thirds its volume of dustbin refuse, and then burned in the furnace.

In other towns the combustion of the refuse in Destructor furnaces has been made available for generating steam in boilers, for the manufacture of manure from human excreta (pail contents), for driving electric lighting machinery, and for other municipal purposes. The clinkers when withdrawn from the furnace can be ground down in a mortar-mill and converted into mortar, bricks, or concrete.

Sanitarily considered, the destruction by heat of the dustbin refuse is far preferable to the sorting method, and economically, where circumstances are favourable, it may very possibly be found to pay expenses.

HUMAN EXCRETA

The table on the next page (Lawes) gives the average amounts, in ounces, of fæces and urine passed daily by an adult male (15 to 50 years of age).

Roughly speaking, an adult male, living on a mixed diet of animal and vegetable food, may be assumed to pass four ounces by weight daily of solid fæces, and 45 to 50 fluid ounces of urine. Taking all ages and both

[1] See paper by Dr. MacLintock in *Public Health*, December 1889.

sexes, the daily amount of excreta per head of a mixed population may be assumed to be 2·5 ounces of fæces and 40 ounces of urine (Parkes).

—	Fresh Excrements	Dry Substance	Mineral Matter	Carbon	Nitrogen	Phosphates
Fæces . . .	4·17	1·041	0·116	0·443	0·053	0·068
Urine . . .	46·01	1·735	0·527	0·539	0·478	0·189
Total . .	50·18	2·776	0·643	0·982	0·531	0·257

From the table it will be seen that human fæces when fresh contain about 25 per cent. of dry solids, and that the urine contains about 3·8 per cent. of dry solids, of which rather more than half (54 per cent.) is urea. A given weight of fæces is as a manure more valuable than the same weight of urine, in the proportion of about 10 to 6; but the weight of the urine passed daily by an individual of a mixed population is sixteen times as great as that of the fæces; consequently the urine passed by an individual in twenty-four hours is worth ten times as much as the fæces passed in the same time, the nitrogen being no less than nine times, and the phosphates nearly three times, as much by weight in the daily urine as in the daily fæces.

Messrs. Lawes and Gilbert have calculated that the average amount of ammonia voided annually by an individual of a mixed population of both sexes and all ages is in urine 11·32 lb.; in fæces 1·64 lb.: total 12·96 lb. The money value of the total constituents (ammonia, phosphates, and potash) is in urine 7*s.* 3*d.*; in fæces 1*s.* 2¾*d.*: total 8*s.* 5¾*d.* But in calculating the value of sewage it is better to take the annual excretion of the individual as being equivalent to 10 lb. of ammonia, worth 6*s.* 8*d.*, more especially as it was stated by the late Dr. Voelcker that nitrogenous organic matters (in which form the nitrogen of sewage principally exists) are worth considerably less than ready-formed ammoniacal salts. It is also evident that it must be impossible to realise practically any such value, because it is impossible to collect the whole of the urine and fæces unmixed with other substances, which greatly detract from the value because they are agriculturally worthless.

WASTE WATERS

The waste waters from houses contain much foul organic matter. The kitchen sink waters are highly charged with decomposable organic matters, especially grease; and the slop-waters contain urine, soap, and dirt from the surface of the body and from clothes.

The waste liquors from manufactories are of very variable constitution. Some of them are very rich in manurial ingredients—e.g. the waste water from flannel washing was stated by the Rivers Pollution Commissioners to be twenty times more valuable as a manure than London sewage.

These waste waters, when mixed with rain water from the roofs of houses and from paved surfaces, with the liquid drainage from midden pits or cesspools, stables, cowsheds, and slaughter-houses, and with the urine from public urinals, form the sewage of the non-water-closeted or midden towns. Such sewage from being stale is decidedly more offensive than that of water-closeted towns, which contains the solid human excreta as well. In the first report of the Rivers Pollution Commissioners it is stated that there is 'a remarkable similarity of composition between the sewage of midden towns and that of water-closet towns. The proportion of putrescible organic matter in solu-

tion in the former is but slightly less than in the latter; whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage. For agricultural purposes ten tons of average water-closet sewage may, in round numbers, be taken to be equal to twelve tons of average privy sewage.' The same report also shows that more persons contribute to a given volume of sewage in midden towns than in water-closet towns, because it is found that the proportion of chlorine is greater in the sewage of the former towns than in that of the latter, the cause of this difference being the increased quantity of water needed by and supplied to the water-closet towns.

Such being the case, it is necessary to bear in mind that in towns where there are middens, or some form of dry closet for the collection of fæcal matters, there is also the liquid sewage to be conveyed away from the houses by drains and from the town by sewers, which sewage is too impure to be admitted into a stream, and must therefore be purified before being so discharged.

CONSERVANCY SYSTEMS

Middens

Until comparatively recent times open midden heaps and pits were, in town and country alike, the almost universal receptacles for the excretal and other waste matters of the habitation. On the midden heaps the excrement was allowed to accumulate, and to diffuse itself from thence for an unlimited time, or until it was required for manure. The disgust excited by these large accumulations of filth above the surface of the ground eventually led to the practice of digging shallow pits in the yards and courts about houses, over which was erected some primitive form of privy. The intention was that the contents of the pits should be removed as soon as they were full; but too often they were allowed to overflow, when the filthy liquids found their way into the cellars of houses or saturated the ground in their vicinity. In any case, being unprotected from rain, the water soaked through the more or less solid midden contents, and percolating through the surface layers of the soil poisoned the water in the neighbouring wells.

The institution of middens, i.e. the setting aside of a special locality where the refuse matters of a house might be deposited, was no doubt an improvement on the state of things which existed in an even more primitive condition of society, where no special places being allotted for such purposes excrement was deposited in any convenient or inconvenient locality. But the pestilential odours that arose from the festering midden heaps and pits, the pollution of the soil around the houses, and the contamination of the wells, were the cause of much of that epidemic prevalence of cholera and fever which was characteristic of the last century and the first half of this, and which experience has shown to be so eminently preventable by improved methods of excretal disposal. That such abominations still exist in many places in this country is only too true. The immense advance, however, in sanitary enlightenment has already effected enormous improvements, and it is likely that the loathsome middens which were formerly so universal will soon be utterly abolished.

Various improvements have from time to time been attempted upon the old-fashioned form of midden pit. These improvements had for their object (1) the removal of the midden from the immediate neighbourhood of the house; (2) a reduction in the size of the pit, so as to limit the accumula-

tion of foul matters, and the lining of the pit walls with brickwork and cement so as to render them impermeable and prevent the saturation of the soil with foul liquids; (3) the preservation of the midden contents in a dry condition (*a*) by roofing over the pit so as to prevent any entry of rain, (*b*) by admixture of the excreta with ashes, and (*c*) by connecting an overflow pipe with a sewer or ditch so as to drain off the more fluid portions.

The provision of an overflow pipe to middens and cesspools when connected with sewers has been found productive of so much nuisance that it is now almost everywhere prohibited. The putrid fluid from middens thus introduced into the sewers carried so much ashes with it as to cause foul deposits, which gave rise to the most offensive gases, and eventually tended to cause a complete stoppage. Besides, if the middens or cesspools cannot be worked without connection with the sewers, it is difficult to see wherein their use lies. For the midden or cesspool drainage pollutes the sewers to an equal, if not to a greater extent than water-closets, whilst the receptacles themselves retain the filthy solids on the premises of the house, when they might with greater advantage be conveyed straight to the sewers.

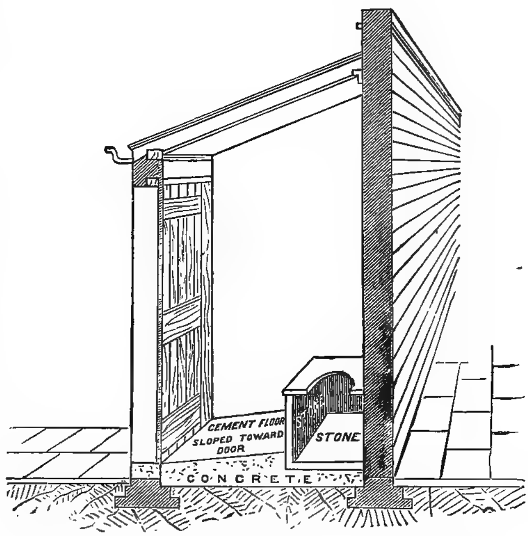


FIG. 164.—Privy constructed in accordance with Model Bye-laws of the Local Government Board.

Most modern regulations require that the midden pit, *quâ* a hole dug into the ground, should be abolished altogether, and that for the pit should be substituted merely the space intervening between the seat of the closet and the floor. In nearly all towns where middens are retained they are now required to be constructed according to certain definite rules. The Model Bye-laws of the Local Government Board for the construction of privies and middens in new buildings are to the following effect :—

The privy (fig. 164) must be at least six feet away from any dwelling, and forty or fifty feet away from any well, spring, or stream; means of access must be provided for the scavenger, so that the filth need not be carried through a dwelling; the privy must be roofed to keep out rain, and provided with ventilating openings as near the top as practicable; that part of the floor of the privy which is not under the seat must be not less than six inches above the level of the adjoining ground, must be flagged or paved with hard tiles, and must have an inclination towards the door of the privy of half an inch to the foot, so that any liquids spilt upon it may run outside and not find their way into the receptacle under the seat; the capacity of the receptacle under the seat of the privy must not exceed eight cubic feet—a weekly removal is then necessitated; the floor of this receptacle must be in every part at least three inches above the level of the adjoining ground; the sides and floor of this receptacle must be constructed of impermeable

materials: they may be flagged or asphalted, or constructed of 9-inch brickwork set and rendered in cement; the seat must be hinged, or other means of access to the contents of the privy must be provided; and the receptacle must not communicate with any drain or sewer.

When middens are constructed according to these rules, there is little danger of percolation of liquid filth into the soil around houses, and in the neighbourhood of wells. The pollution of the air by the excreta is reduced to a minimum, if their dryness is ensured by the proper application to them of ashes and cinders, and no slop-waters are thrown in. During removal, however, some offensive effluvia must of necessity escape into the air. The success of the system depends to a large extent on efficient inspection by the sanitary officers, and on proper scavenging arrangements.

There can be no doubt, however, about the fact that any form of midden is unadvisable, from the great expense of scavenging and the inconvenience caused by the frequent visitations of the scavengers, especially as they have to disturb the contents of the middens in digging them out. These frequent visitations are most unpopular, and any plan which makes such visits as infrequent and as short as possible, or does away with them altogether, is sure to be greatly preferred.

The Pail System

We have seen that middens can only be tolerated when so reduced in size as merely to constitute the space between the closet seat and the floor. It is obvious that middens of this limited capacity may most advantageously be replaced by movable receptacles, such as pails or tubs, placed under the closet seat for the reception of the excreta. The removal of the excreta is thereby greatly facilitated, and there is no pollution of the air from disturbance of the contents of the pails, as there always must be when the contents of middens are dug out and conveyed to the night-soil carts. On the arrival

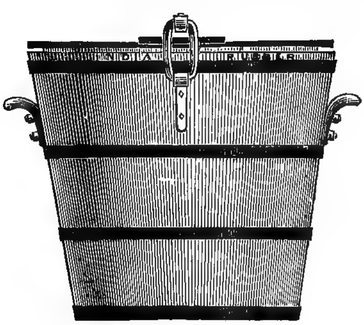


Fig. 165.—Rochdale pail.

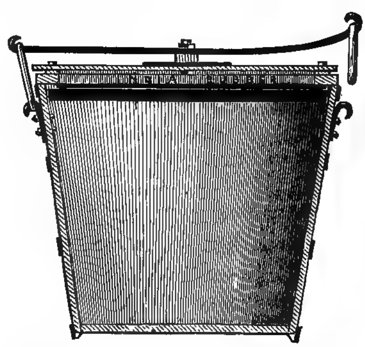


Fig. 166.—Rochdale pail, with Harescеugh's spring lid.

of the scavenger the lid of the pail is adjusted, the pail is taken out to the scavengers' cart, and a clean empty one is left in its place.

The pails (figs. 165 and 166) may be of galvanised iron or tarred oak: they should be provided with close-fitting lids, which hermetically seal the pails and prevent any leakage or escape of effluvia at the time of their removal to the scavengers' carts, when the contents are unavoidably liable to some disturbance; and the capacity of each pail should not be greater than two cubic feet. They should, of course, be very strongly constructed, and capable of resisting the rough usage to which they may be subjected, as well

as be perfectly water-tight. On the whole, tarred oak pails have been found to answer better than galvanised iron ones, as they are less expensive, last longer, and are far more easily repaired. When the pails have been emptied of their contents at the town depot, they should be well washed with water, jetted out of a hose under high pressure, and subsequently disinfected with chlorinated lime. Wooden pails require retarring every two or three months.

The structure of the closet may be very similar to that described as recommended for a midden closet. It should be well roofed, the roof being provided with louvres for ridge ventilation, and the door should be so constructed that, when closed, open spaces may be left above and below for light and ventilation. The floor should be raised above the level of the adjoining ground and flagged, and the pail placed on the floor under the seat. The seat may be hinged to ensure a more complete covering of the excreta with house cinders and ashes, when these are used, and to allow of the pail being removed; or the back wall of the closet may be provided with a door to effect the latter purpose. The pail should be removed at not longer intervals than once a week, and a clean one substituted for it, this plan being far preferable to that of emptying the pail contents into the night-soil cart, and then replacing the pail after a more or less perfunctory attempt to clean it.

From a sanitary point of view it is most important that the pail contents (fæces and urine passed at the time of evacuation) should be kept as dry as possible. A dry condition can only be effected by adding to the pail contents some dry and absorbent substance such as ashes, charcoal, or dry earth, or by lining the pail with some absorbent material. Left to themselves, the mixed fæces and urine in the pails are in a more or less liquid condition, and rapidly tend to undergo putrefactive changes, giving rise to the formation of fœtid gases (organic vapours and compounds of sulphur and ammonia). If, however, it is intended to create a saleable manure, ashes, charcoal, or earth should not be used, and all kitchen refuse and garbage should be kept out of the pails, as it is most essential to collect the fæces and urine in as pure a condition (i.e., unmixed with valueless substances) as possible. In such cases the pail contents cannot be kept dry, and sanitary considerations are sacrificed to ensure commercial profits.

In some towns, such as Nottingham, the authorities find it convenient to remove all the solid house refuse in one receptacle, so that the pails become the receptacles for the solid kitchen refuse, dust and ashes, as well as for the excreta. Here, of course, commercial profit from the sale of manure is not looked for, but the town being situated in the centre of an agricultural district there is no difficulty in disposing of the manure, such as it is.

By keeping the chamber urine out of the pails, much fertilising material is excluded, as the chamber urine constitutes at least nine-tenths of the total daily excretion of urine. But it would be impossible to keep the pail contents dry if chamber slops were thrown in, and these must, therefore, be carried away from the houses in drains with the other waste waters. It has even been attempted to separate the urine passed at the time of evacuation from the fæces, in order to ensure dryness of the pail contents. These 'urine-separators' have, however, not been found to answer their purpose, and they are more especially undesirable, inasmuch as they introduce a complication into a system the chief merit of which is its simplicity.

In the Goux system it is attempted to secure dryness of the excreta by lining a wooden tub (fig. 167) with a layer of refuse sawdust, shoddy, tan, or other absorbent material, to which is added a little soot, charcoal, gypsum, or other dryer or deodoriser. These matters are pressed closely to the bottom and sides of the tub by means of a cylindrical mould (fig. 168), which is after-

wards withdrawn, leaving a cavity in the centre of the materials for the reception of the excreta. On no account should chamber slops be thrown into the tubs, and the tubs themselves should only be in use for two or three days, otherwise the absorptive capacity of the lining materials is exceeded, and the tubs will be found to contain liquid dejections. The system has been in use at Halifax, and on the whole has worked well, the closets, when well managed, being generally found clean and free from offensive smells. House ashes and dry rubbish are collected in a separate pail, so that the tub contents are merely the excreta in a more or less pure condition.

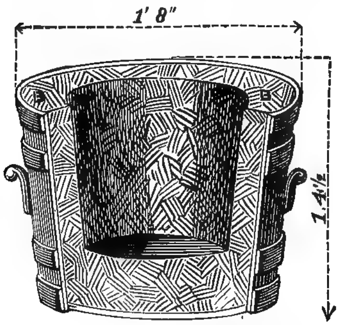


FIG. 167.—Goux pail.

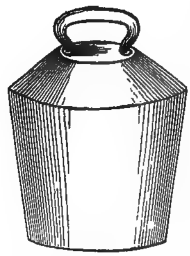


FIG. 168.—Goux mould.

As before stated, another method to ensure the dryness of the excreta is the addition of ashes, charcoal, or dry earth in suitable quantities to the contents of the pails after each use of the closet. These substances not only act as dryers, but very largely also as deodorisers, so that ash, charcoal, or earth closets, if rightly used, are far less offensive than the pail closets where these substances are not in use.

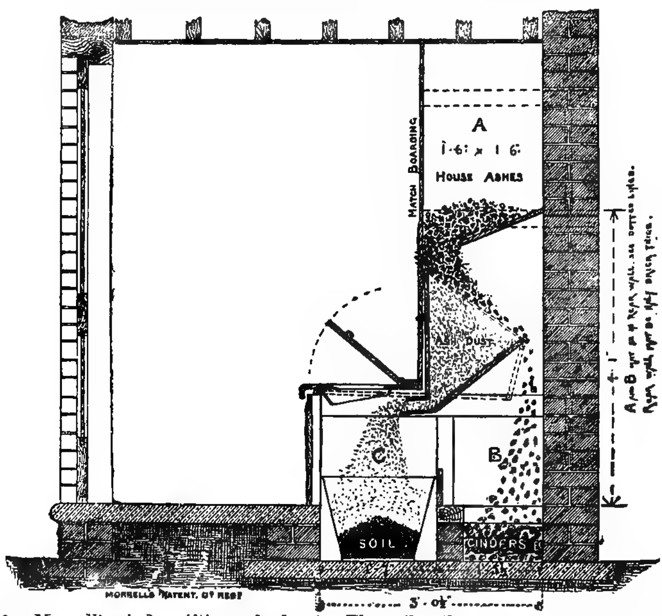


FIG. 169.—Morrell's cinder-sifting ash closet. The soil pail is removed through a side wall.

ASH CLOSETS

Sifted house cinders and ashes may be collected in a box and thrown by a handscoop into the pail after each use of the closet; or by a mechanical arrangement of sieves fixed in a hopper placed above and

behind the pail, the cinders may be sifted and the fine ash deposited automatically on the pail contents by means of a self-acting seat arrangement, or the same result may be accomplished by pulling up a handle (figs. 169 and 170). The cinders which do not pass through the sifter may be used again as fuel. When properly sifted, the fine ashes form very efficient desiccators and deodorisers; moreover, they are always to be found on the premises of any house, unlike charcoal or dried and sifted earth, and they would have to be removed in any case by the sanitary authority.

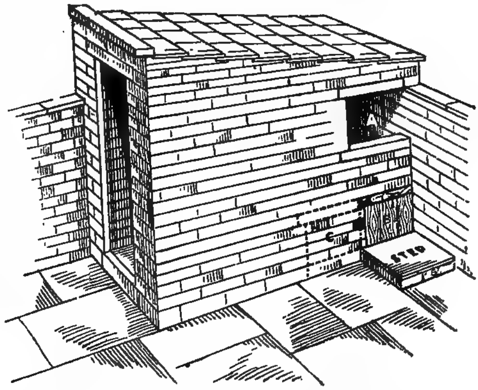


FIG. 170.—External view of Morrell's ash closet, showing opening, A, for putting in ashes, and door, B, for removing sifted cinders. A door may be made at C for removing the soil pail.

CHARCOAL CLOSETS

Wood charcoal and a charcoal obtained by carbonising sea-weed have been used instead of ashes. The same kind of closet, with an automatic apparatus for supplying the charcoal, is suitable as for the ash closet, or a box and scoop may be used. Of the sea-weed charcoal (Stanford's process) it is stated that only $\frac{1}{2}$ lb. is necessary for each use of the closet, and this is found to be equivalent in deodorising power to $1\frac{1}{2}$ lb. of dry earth. The charcoal itself contains 63 per cent. of carbon, 34 per cent. of ash, and only 2·6 per cent. of water. On removal from the closet the mixed charcoal and excrement may be recarbonised by burning, and may then be again used for the same purpose. The products of distillation from the recarbonisation process when condensed consist of ammoniacal liquor and tar, and from the liquor sulphate of ammonium and acetate of potassium can be obtained. After several uses in the closet the charcoal becomes highly charged with potash and phosphates, and when mixed with the ammonia distilled from it forms a very valuable manure.

Neither charcoal nor ashes have any such disintegrating action on the excreta, as we shall see further on the dry earth has. A section through the contents of an ash or charcoal closet pail shows the excrement retaining its form, and the paper unchanged, but the whole mass is dry and odourless. Nevertheless any assumption that mixed excrement and charcoal or ashes may for this reason be safely stored for long periods of time in the vicinity, or within the precincts, of houses would be entirely unwarranted. The only safe plan is to arrange for as frequent removal of the contents of ash and charcoal closets as of the simpler pail closets.

There can be little doubt that Stanford's sea-weed charcoal is far more efficient than ordinary sifted house ashes. On the other hand, a system of charcoal closets would be far more costly to maintain. There is the cost of manufacture of the charcoal and its conveyance to every house, and this is likely to greatly exceed any returns that may be obtained by distilling the mixed excrement and charcoal and selling the products so obtained.

In order to deodorise the contents of pails in which excreta are collected, it has been proposed to add a mixture of soot and salt, which has been found very effective for this purpose, although its drying action is practically *nil.*

Earth Closets

It has long been known that earth of suitable quality is a very efficient deodoriser of excremental matters. For centuries past the Chinese have been accustomed to collect with extreme care all human excremental matters, and to convey them to their fields for enriching the earth, knowing as they do the valuable fertilising ingredients contained in the excreta. And in this custom, originated by the thoughtful thrift for which the Chinese are famous, is also contained the practical application of the sanitary rule, 'the sewage to the soil,' which is the highest development of our most enlightened views on the utilisation of human refuse. Not only is the earth the better for the sewage, which returns to it in an assimilable form the nitrogen and inorganic salts taken away in the crops, but on a large scale the earth is the only substance available for converting the noxious products of human and animal excretion into inoffensive and useful matters.

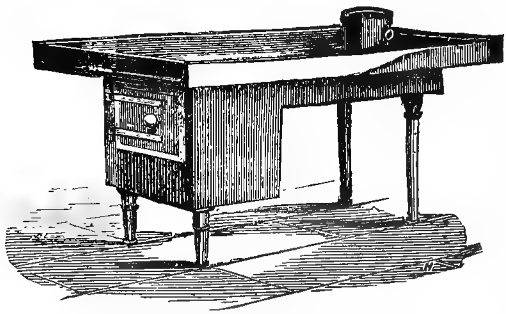


Fig. 171.—Stove for drying earth.

The dry earth system, the invention of the late Rev. Henry Moule, is, however, the very reverse of the plan upon which all the other systems proceed. It proposes to bring a certain quantity of earth to the manure, while all the others take the manure in some form or another to be placed upon the earth; in other words, a sufficient quantity of dry earth is to be brought into every community where this system is at work, to completely deodorise and render inoffensive all the excremental matters of the population.

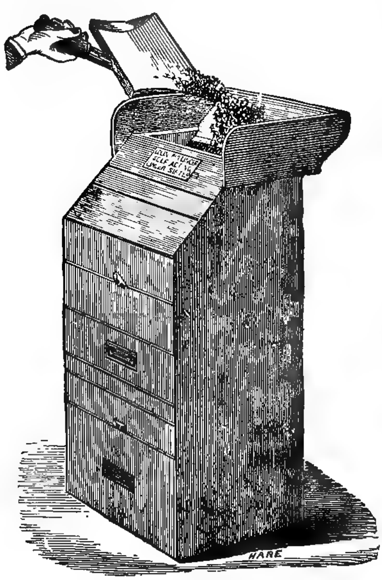


Fig. 172.—Earth-sifter.

The best kinds of earth for the purpose are loamy surface soil, vegetable mould, brick earth, and dry clay. Sandy, gravelly, and chalky soils are not efficient deodorisers. The earth must be dried before use over a stove (fig. 171) or on a hot floor, and then passed through a riddle or sieve (fig. 172), so as to thoroughly sift it, the finer portions only being used. For large communities these operations should be conducted at one spot, and on an extensive scale; but for separate establishments, such as houses or institutions in the country, each household would have to prepare its own earth.

The excreta are deposited in a pit of an approved sort, or in a pail (fig. 173) or tub placed under the closet seat, and $1\frac{1}{2}$ lb. of dried sifted earth must be applied *in detail*—i.e. each particular stool must be covered at once with this quantity as soon as deposited. This quantity ($1\frac{1}{2}$ lb.) is

sufficient to remove all smell from the stool, and to form a compost with it which remains inoffensive as long as it is dry. Less earth than the above specified amount is said to be insufficient, whilst more is useless. A certain action takes place in the intimate mixture of earth and excrement which results in the complete disintegration of the fæcal matters. After a time, excremental matters, and even paper, can no longer be detected as such in the mixture. After keeping and redrying the compost so formed, it may be used over again in the closet, and has the same action as the original dry earth; but inasmuch as this repeated use does not increase in a corresponding degree the manurial value of the compost, there is no particular advantage in doing so from an economical point of view, if we except the reduction in bulk of the matters that eventually require removal from the house, which is only a matter of importance in the case of towns, and does not apply with equal force to country houses.

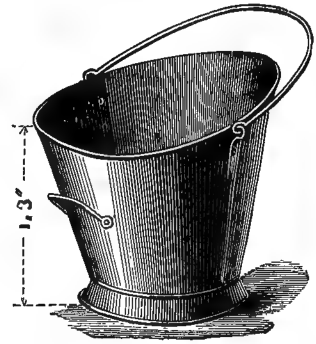


FIG. 173.—Pail holding twenty charges.

The closet suitable for the earth system may be very similar to that described under ash closets. A hopper of metal or wood is placed above and behind the seat, and the requisite quantity of dry earth is shot into the pit or pail by a simple mechanical contrivance connected with a handle (fig. 174) or self-acting seat arrangement.

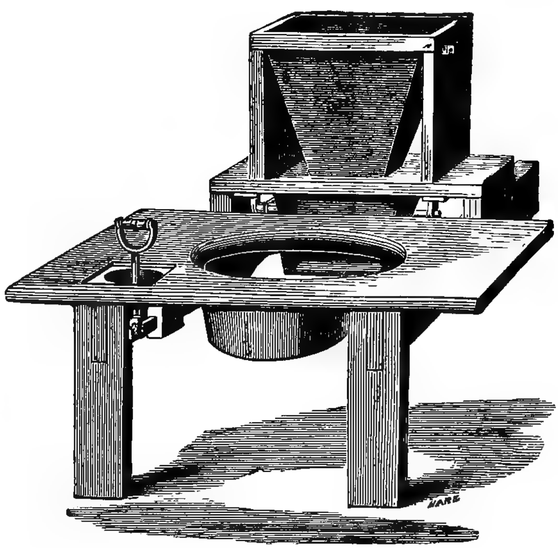


FIG. 174.—Earth closet, with pull-up handle apparatus.

In large establishments the tank shown in fig. 175 can be used. It holds thirty-six charges, and being on wheels is more easily removed than a pail holding the same amount. It is especially useful for schools, barracks, factories, &c., where the closets are much used, and where smaller pails might in the course of a day become overfilled.

The contents of the pails must be kept dry, or fermentation results with the disengagement of foul gases; consequently no slop waters must be thrown into them, and even chamber urine must be excluded unless sufficient extra earth is added to render the contents quite dry.

The compost produced by the passage of the earth even five or six times through the closet has but little agricultural value as a manure. The British Association Sewage Committee reported of such manure that it was 'no richer than good garden mould.' The committee found that the average gain of total nitrogen to the soil by each passage through the closet was

scarcely 0·15 per cent.; and they remark upon this point that 'if only two pounds of soil were used per head per day, and as much as one-third of the total nitrogen voided in fæces and urine by an average individual in twenty-four hours were collected with it in the closet, the nitrogen so added to the soil would amount to about 0·5 per cent. of its weight by each use, or by using five times to nearly 2·5 per cent. Probably in practice a larger amount of soil and a smaller proportion of the total nitrogen daily voided would be collected in an earth closet. The increased percentage of nitrogen actually found is seen to be less than one-third of the amount calculated on the foregoing assumption. There can indeed be little doubt that there is a considerable evolution of nitrogen in some form; and the probability is that it takes place to a great extent as free nitrogen.'

This escape of nitrogen in a free state from the manure when kept may partly account for its deficiency in fertilising properties; but it must also be recollected that the compost is largely diluted with valueless earth, and that there is absent from it a large proportion of the daily urine of each individual.

The late Dr. Voelcker estimated the value of the soil passed five times through the closet at 7*s.* 6*d.* per ton, and it is certain that it would only pay the cost of carriage to a very short distance, even if disposed of free of charge.

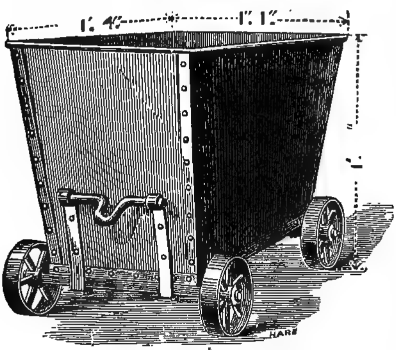


FIG. 175.—Tank holding thirty-six charges.

Although the commercial value of the earth-closet manure is so small, it is found of considerable use in gardens, where it can be applied without going to the expense of any carriage. It forms a rich mould, suitable for garden and pot plants, and yet not so rich that it has to be diluted with ordinary earth. In country houses with gardens, therefore, the earth compost has a considerable practical value.

From a sanitary point of view the earth closet is superior to any other form of pail closet. When properly managed, the closet is free from any offence; the process of emptying the pails is unaccompanied by any foul smells; and the system is one which may be adopted in country houses and villages, where earth of suitable quality is easily procurable, and where the compost can be applied on the spot to fields or garden lands. It is, however, especially applicable for temporary gatherings, such as fairs and camps. It was, indeed, in use at the annual Volunteer meetings at Wimbledon for some years, and answered very well.

MANUFACTURE OF MANURE

We have already seen that the earth-closet manure requires no further manipulation after removal from the closets, but can be applied direct to land. It is somewhat different, however, with the crude contents of middens and pails. In some towns situated in agricultural districts, where there is a demand in the immediate locality for the coarser sorts of manure, the contents of middens or pails need merely be mixed with a certain portion of fine ash, when farmers in the neighbourhood are willing to remove it. This manure is, however, only well suited for heavy clay

soils; for most soils the admixture with ashes renders it comparatively worthless.

In many of our large towns where the midden or pail systems are still in vogue, it has become the practice of recent years to convert the crude pail or midden contents (without admixture with ashes) into a dry manure of a much less offensive character, which can be packed in bags or casks, and sold at a distance.

The following account of the process, as usually carried out, is taken from a report (1881) of Dr. W. Sedgwick Saunders upon 'Some new Methods of Disposing of all Kinds of Refuse by Cremation.'

The ashes, &c., collected in tubs are screened in an automatic cinder screen; the fine ash is mixed with such portion of pail contents as will furnish a manure sufficient to satisfy the local demand; the coarse ash is discharged into a form of furnace called a 'destructor,' which is made to destroy and reduce any refuse material that contains only a small portion of combustible matter. The heat generated by the combustion passes under and through a multitubular boiler, and generates steam for furnishing the power required for working the whole of the machinery. The clinkers from the destructor, if not required for other purposes, are passed into a mortar mill, which reduces them to powder that can either be sold as sand or made, by the addition of lime, into an excellent and tenacious mortar.

The sweepings from the markets and streets are passed through a 'carboniser,' a furnace which converts all vegetable material into charcoal. The charcoal produced is a powerful deodorant; and it was proposed to use a portion of it in each pail, previous to its leaving the depôt, to deodorise the matter collected, the remainder to be sold.

The contents of the pails are mixed with a small portion of acid, to fix the ammonia, in an air-tight store tank, where the thicker portion of the material settles to the bottom. The thin part of the contents of the tank is drawn off into two evaporators, which are tall cast-iron cylinders, each containing, near its lower end, a drum-shaped heater, precisely resembling a multitubular steam boiler. These cylinders are partially filled, and the heating drums are covered with the thin liquid; steam is then introduced within the heating drums, and the liquid becomes partially concentrated. When the contents of these cylinders are sufficiently concentrated, and have lost, by evaporation, the greater portion of their water, they are drawn off into a 'Firman's dryer,' and the thick portions of the pail contents which settle in the store tank are also admitted into the dryer. This machine consists of a steam-jacketed horizontal cylinder, traversed by a steam-heated axis and by steam-heated revolving arms, and is furnished with scrapers to keep the inner surface of the cylinder free from accumulations of dried excreta.

The pail contents are admitted into the dryer at the consistency of thin mud; after treatment they emerge as a dry powder, resembling guano in appearance and quality, and estimated by analysis to be worth from 3*l.* to 6*l.* per ton. The odorous gases given off during the process are all passed through the Destructor furnace and destroyed. From the time the liquid material enters the store tank, until it finally emerges as a dry powder, there is no opportunity for odour to escape into the air, as it is kept closely under cover.

The destructor and the carboniser are the inventions of Mr. Alfred Fryer, who also originated the system by which the collected ashes and cinders are alone sufficient to furnish the heat necessary to evaporate the pail contents.

At Manchester a portion of the town refuse is dealt with in this manner

at the Corporation's sanitary works at Holt Town. The cinders collected are mainly used as fuel for the furnaces of the boilers which work the machinery, effect the evaporations, &c.; the animal matters are converted into dry manure, soap, and lubricating grease; and the clinkers from the furnace are made into mortar, bricks, and concrete. The animal matters from which the manure is made include human excreta (pail contents), slaughter-house refuse, bones, dead animals, fish, &c. This manure contains 2·73 per cent. of ammonia, 2·36 per cent. of phosphoric acid, and 15 per cent. of moisture. It is sold at 3*l.* per ton.

Systems similar to the above are now in operation at Glasgow, Leeds, Bradford, Warrington, Rochdale, Stafford, Bolton, Birmingham, Blackburn, Rotherham, Derby, Bury, and Nottingham.

The deputation from the Commissioners of Sewers of the City of London which visited the works established at Leeds, Bradford, Warrington, and Manchester in 1881, came to the unanimous conclusion that the system is sound in theory and desirable in practice, and that it offered enormous advantages upon sanitary grounds. 'Not only did they see a work consisting of poisonous and disgusting elements dealt with, and satisfactorily disposed of, without nuisance of any kind, but learnt that products having a marketable value can be, and are, produced without any infraction of true hygienic principles, whilst at the same time they may have the effect of materially reducing the expenses' (Dr. Saunders' Report).

Cesspools

Until lately the terms 'midden pit' and 'cesspool' were regarded as synonymous. But it has now become more usually the practice to apply the term 'cesspool' to those receptacles excavated in the soil which are destined to receive the liquid waste waters of the house as well as the excreta, whilst the 'midden' is the pit for the reception of excrement only, or of excrement and solid rubbish, the waste waters being got rid of by other means. Under the primitive conditions which existed in nearly all towns until within the last forty or fifty years, the waste waters of the houses in the poorer streets (the slops and kitchen waters) were thrown into the street gutters, which carried them away to the nearest watercourse. In more recent times, since the introduction of drains and sewers, the house waste waters of the midden towns are now conveyed to the sewers by slop sinks and gully holes connected with a drain. The midden pits still remain for the reception of the more or less solid refuse of the house.

It is therefore obvious that, whereas the contents of middens are, or should be, in a more or less solid condition, the contents of cesspools must necessarily be in a liquid condition, the volume of the liquids they receive preponderating so immensely over that of the solids.

Prior to the year 1815, when the law which prohibited the passage of sewage from houses into the sewers was repealed, in London and other large towns nearly every house in the wealthier streets had one or more cesspools on its premises for the reception of solid and liquid excreta and waste waters. These cesspools were often of large size, and situated under the basements of the houses. When, in the year 1847, it became compulsory to drain houses into the sewers, many of these cesspools were filled in and abolished; but some of them escaped observation, and to the present day it is no unusual thing to find in the basements of town houses one or more cesspools, of the existence of which the owners or occupiers are profoundly ignorant.

At the present day cesspools are still largely in use, and fresh ones are

being constantly constructed for isolated houses in suburban and country districts where there are no sewers. In these houses, inside water-closets are insisted on by tenants of the better class, so that the cesspools, which are excavated in the yard or garden adjoining the house, become the receptacles for the water-closet sewage and for waste waters of the house.

The desirability or otherwise of cesspools depends greatly upon circumstances. For country houses with large gardens the cesspool system offers some advantages. If a series of two or three cesspools are constructed communicating with each other by overflow pipes, most of the solids are retained in the first of the series which receives the house drain. The overflow cesspools receive the liquid sewage, which can from time to time, as desired, be pumped up and used as liquid manure for kitchen gardens, orchards, &c. The solids very gradually accumulate in the first cesspool, from which, when full, they can be extracted by buckets and dug into the ground. All the cesspools should of course be constructed so as to be impermeable to fluids, and even then should be at a considerable distance from any well; and in no case should they be provided with an overflow pipe to carry surplus sewage into a stream supplying drinking water. Perhaps a better plan is to intercept the solids in the sewage before it arrives at the cesspool by placing a strainer in a manhole chamber on the drain. The most offensive matter is thus entirely kept out of the cesspool, and can be dug into the ground as soon as collected, the collection taking place daily.

Where, however, houses are more closely crowded together, and the plot of land attached to each is of size insufficient to utilise the sewage by its application to the soil, the cesspool system is liable to become an unmitigated nuisance. The periodical visitations of the night-soil carts become then a necessity. If in a sufficiently liquid state, the cesspool contents are pumped up by manual labour into troughs and so conveyed to the carts, or, if too solid for pumping, the contents must be drawn up in buckets. In either case the pollution of the air is nauseating and disgusting to a degree, and the offensive odours are wafted by the wind to considerable distances, so that all the inhabitants of the neighbourhood become aware of what is in progress.

There are also other very distinct dangers attached to the cesspool system. Cesspools are very frequently so constructed as to allow all the liquid filth to percolate through their walls into the surrounding soil, the solids only being retained. In unlined cesspools dug in porous soils, such as sand, gravel, and chalk, the liquids escape with the greatest readiness, and the cesspool but very rarely requires emptying. This is an advantage, however, which is far more than counterbalanced by the contamination of the subsoil in the close vicinity of houses, and by the almost certain danger of polluting wells, springs, and other sources of underground water supply. Such pollution is especially likely to occur in the case of cesspools dug in the chalk. The liquids rapidly drain away through the cracks and fissures in the chalk walls, and even the solids disappear, with the result of polluting the water below in the subterranean reservoirs—a water which is naturally of very great purity. In the case of sand and gravel, a cesspool is exceedingly likely to contaminate the surface wells in the neighbourhood.

The model bye-laws of the Local Government Board for new buildings require that the cesspool should be at least 50 ft. away from a dwelling, and 60 to 80 ft. distant from a well, spring, or stream. It must have no communication with a drain or sewer in sewered districts; its walls and floor must be constructed of good brickwork in cement, rendered inside with cement, and with a backing of at least 9 inches of well puddled clay around and beneath the brickwork. The top of the cesspool should be arched over, and means of ventilation provided.

The object of these rules is to secure an impermeable receptacle for the reception of the sewage, which will prevent pollution of the subsoil and of underground water supplies. The reasons for not connecting a cesspool with a sewer by means of an overflow pipe have already been alluded to (see p. 813).

Constructed in accordance with these rules, the possible dangers of cesspools are reduced to a minimum; but the principle, which is bad, remains the same, for it cannot be too strongly insisted on that in the vicinity of houses to retain in any receptacle, however well constructed, a large collection of solid and liquid excrement, there to undergo putrefaction with the formation of offensive gases, is a violation of every sound sanitary principle.

Continental Systems

In many Continental towns the cesspool system is still largely adhered to. Huge pits (*fosses permanentes*) are excavated under the courtyards of the houses, and are lined with cement, so as to be impervious. In Paris and some other towns these cesspools must be provided with a ventilating shaft reaching up some feet above the roof of the house. Sometimes two receptacles are constructed side by side, and communicating with each other by means of small apertures through which liquids only can pass. By this means the solids are retained in one receptacle, whilst the liquids pass into the other; and this separation is found to materially retard decomposition. Each of the receptacles is provided with a ventilating pipe.

The closets are usually connected directly with the cesspool by means of the soil-pipe, starting from the soil-pan, when there is one, or from the hole in the lead or zinc-lined floor of the closet, when there is not. There is often no sort of trap at either extremity of the soil-pipe, so that the putrid gases formed in the cesspool rise up into the interior of the house. The soil-pan and pipe are usually only flushed when slops are thrown down.

As a general rule, the cesspools are constructed of such a size that they only require to be emptied once in three or four months. As a matter of fact, being but rarely impervious, they allow some of their liquid contents to escape into the surrounding soil, and so only require emptying at even longer intervals.

Until recently the cesspools were emptied by pumping their contents through hose into large cask-shaped carts (*tonneaux*) sent for the purpose at night when required. The nuisance engendered by this process has now caused it to be largely superseded in Paris, Rheims, Metz, and other Continental towns, by a method of emptying the cesspools by pneumatic pressure.

One of these methods which is coming largely into use is that designed by Talard. A steam vacuum pump is attached to a small portable locomotive engine, to exhaust the air from the receiver or tonneau. These receivers are barrel-shaped, of a capacity of about 3½ cubic yards, and are made of light steel plates. Each receiver is mounted on framework on four wheels, and can be easily drawn from place to place by a pair of horses. It is fitted with a glass gauge at one side to show how full it is, and has a large full-way valve underneath, to which a strong flexible 5-inch tube is attached.

On the cesspool being opened this tube is plunged to the bottom of the contents, its other end being connected with the receiver, which has itself already been connected with the engine by a smaller tube from its upper part. The engine being started, the noxious gases are first extracted from the cesspool, passed through the furnace and burnt; the air is then exhausted from the receiver, and on the valve being opened the contents of the cesspool

rush up, filling the vacuum in about three or four minutes. The valve is then closed, the pipes disconnected, and the receiver taken away to be replaced by others, until the cesspool is entirely empty. It is stated that by this process the contents of a cesspool can be extracted at the rate of about twenty cubic yards per hour.

The receivers can either be discharged into close barges, specially constructed for the purpose, in which case the pipe is connected at one end to the receiver and at the other to the barge, so that the contents are transferred from one receptacle to the other by gravitation, without being exposed to the air; or they can be emptied on to the land in the usual manner for fertilising purposes.

The special feature of Talard's system as distinguished from other pneumatic processes is the invention of a mechanical joint to connect the lengths of hose. This joint is both water- and air-tight, and can be made in two or three seconds by an ordinary labourer, and as easily disconnected.

There can be little doubt but that the pneumatic system has most materially diminished the nuisance formerly inseparable from the process of emptying. Not only was it obnoxious to all in the neighbourhood, but the foul gases generated by the disturbance of the contents of the cesspool were a distinct danger to the workmen. Asphyxial poisoning (*le plomb des vidangeurs*) from great excess of sulphuretted hydrogen and corresponding diminution of oxygen was occasionally the result of their operations, more especially where the contents had to be raised in buckets to the surface; and the Paris scavengers were described by Parent Duchatelet as suffering much from headaches and ophthalmia, which latter (*la mitte des vidangeurs*) is generally attributed to the large amount of ammoniacal compounds present in the foul air.

Movable tubs or pails (*fosses mobiles*) are also in use in some Continental towns. As a rule, the tub or tonneau, capable of holding fifty or sixty gallons of liquid, is placed in the basement, and is connected with the closets above by means of an iron or stoneware soil-pipe. The tub is fitted with a spring lid, which is adjusted when the tub is full, before its removal by the scavengers. As with the *fosses permanentes*, there are, as a rule, no traps or valves fixed anywhere to prevent foul gases rising into the house. Reliance is placed upon a ventilation pipe which is connected with the soil-pipe, and carried up to the roof, and upon the lid to the closet, which, being constructed with a rim fitting into a groove in the soil pan, is supposed to be air-tight. As a matter of fact, however, foul gases find an easy exit into the house when the closet is in use and the lid is raised. In some cases the *fosses mobiles* are provided with separators for the separation of the liquids from the solids, and it is then usual to carry the liquid contents into a cesspool.

In Paris the contents of the *fosses permanentes* and *fosses mobiles* are converted into manure (*poudrette*) by a process which would hardly be tolerated in this country. The tonneaux are carried away to the works outside the town, where they are emptied into the highest of a series of basins ranged one above another. Here they are exposed to the air for some time, and while the liquid parts run away into the lower basins, the undissolved solids subside in the higher ones. The liquids are reduced in quantity by spontaneous evaporation, but they have for the most part to be pumped away, generally into the nearest watercourse. The solid part which subsides is dug out of the pits, further dried by being spread out on a large surface of ground, and stirred about continually, piled up when nearly dry in immense heaps, and left for a year at least—often for several years. It is then sold under the name of *poudrette*. It has the aspect of a greyish-black

earth, light, oily to the touch, very pliable, and spreading a peculiar, disagreeable, and nauseous odour.

It will be readily understood that this process of spontaneous evaporation of moisture from immense heaps of putrid refuse must spread the effluvia for miles around, and cause a nuisance, compared with which the worst managed of our sewage works would be described as inoffensive.

COMPARISON OF CONSERVANCY METHODS

From what has already been written on this subject it will be apparent that the best system from a sanitary point of view is that which provides the most perfect means for preventing the decomposition of the excretal matters during their period of retention on the house premises, and secures their removal with the greatest frequency and with the least offence.

The midden system, even with middens constructed on the best approved plan, stands condemned by reason of the nuisance engendered when their contents are removed. The same remark applies with even stronger force to cesspools, especially in towns.

We are therefore entitled to insist upon some form of movable receptacle in which excretal matters may be collected and removed, and practical experience and theory alike point to the pail system as the conservancy system which is best suited for use in towns.

Where pails are in use the removal may be carried out twice or three times a week; there is no necessity for the pail contents to be disturbed until they arrive at the depôt, and consequently nuisance in the neighbourhood of houses is, to a considerable extent, avoided, if the removal is sufficiently frequent. There is, besides, another advantage which movable pails have over fixed receptacles. Where compulsory notification of infectious disease is in force, the local authority receive early information of cases of enteric fever. The pails removed from infected houses can be marked, their contents disinfected, and clean pails containing strong chemical solutions supplied in their place. In this manner it will be possible to destroy much of the poison excreted by a case of enteric fever, and very materially to place a limit on its spread.

We have already seen that to keep the pail contents in a dry and inoffensive condition some desiccating material must be added, but that to convert the pail contents into a profitable manure they ought to be collected unmixed with other substances. The great difficulty in getting rid of the crude pail contents when mixed with ashes has induced numerous towns to essay the manufacture of manure; but we are strongly of opinion that that system which gives the best sanitary results is likely in the long run to prove the cheapest, and that admixture with ashes is one of the best methods to secure this end.

It must be obvious that in towns ashes are the only deodorants which are in any way practicable. They are part of the domestic refuse of every house, and would have to be removed in any case, and their preparation by sifting involves but very little trouble, even if cinder-sifting ash closets are not in use. The quantity of dried and sifted earth that would have to be brought into a town, were earth closets in general use, would be enormous. Then, in every house accommodation must be provided for storing the earth and for keeping it dry, and if the earth is to be used more than once the compost must be stored on the premises and be again dried before use. The quantity of matter to be removed from the houses by the local authority would be

far in excess of that of the pail and ashes system, and when collected its value for fertilising purposes is so low that there would be even a difficulty of disposing of it if given away, for it would not pay to remove it.

Although, then, in towns where a conservancy system is unavoidable ash closets appear to best meet the requirements, it must not be forgotten that the success of this system depends largely on individual care on the part of the householder, upon active sanitary inspection by the local authority, and upon a well-organised scheme of scavenging—in fact, upon arrangements of considerable complexity, which are liable to failure at unexpected times and from unexpected causes. The expenses of this form of scavenging are very high, and the more frequently the pails are removed the greater is the cost, so that there is always an inducement to economise at the expense of health. The pail system can be made to depart most from the principle of the conservancy method, i.e. the retention of excretal matters on the premises of houses, by adopting a plan of very frequent removals, but practically the excessive cost of such a plan is found to be prohibitory.

The other great objection to all conservancy systems is the fact that they only deal with a fraction of the waste matters of a community, and fail to deal with a liquid refuse of a highly polluting character, a liquid which causes the sewage of the so-called midden towns to be little, if any, less impure than that of water-closet towns; and so conservancy entirely fails to provide any sort of solution to the question of disposal of sewage.

Neither can it be denied that dry closets of all kinds are not regarded with favour when placed inside houses. To most people the retention of excrement in any form within the house is objectionable, and this view of the matter cannot be regarded as a mere prejudice. We are not yet in a position to assert in any way positively that excreta, even if fairly deodorised by dry earth or ashes, are under all circumstances innocuous. And, besides, there is always the possible danger of slops being carelessly thrown into the dry closet, when but a short time would be required to convert what was before fairly tolerable into a most intolerable nuisance. On the whole, then, we must conclude that dry closets are not applicable within houses, and that they should invariably be placed outside the house in such a position that a free current of air can always traverse the space between them and the house.

THE WATER-CARRIAGE SYSTEM

By this system is meant that all the human excretal matters of the community—solid as well as liquid—are, together with the waste waters, conveyed away from the houses in drains, and from the town in sewers. The force which conveys them is gravitation, and this is enabled to exert its power by reason of the liquid condition of the sewage. The solids of the sewage, whether solid excreta or solid waste particles contained in the house waters, are so insignificant in volume in comparison with the liquids that they are carried along with ease in the flowing current. No additional water is required to enable the liquid wastes of the house to carry with them the solid excreta; but in order to render the passage of the latter, when deposited in water-closets, as quick and perfect as possible, and also to ensure cleanliness of the water-closet apparatus, soil pipes, and drains, water is used to flush these receptacles and to carry the excrement rapidly away down the soil drains into the street sewer.

By this system, therefore, there need be no retention of excretal matters on the house premises. Its leading principle is to convey them away from

the house, and subsequently from the town, as quickly as flowing water will do it. This is the great contrast between the water-carriage and all conservancy systems; but, besides this, it is evident that the force employed in water carriage, viz. gravitation, costs nothing, whereas the manual operations of scavenging removal in the conservancy systems are very costly.

We have already seen that every town must have a system of sewers for conveying away the waste waters from the houses and streets, and that these waste waters are of very nearly as objectionable and polluting a character as if they contained the solid human excreta. It therefore follows that whatever precautions are necessary to be taken in the construction and maintenance of the sewers of water-closeted towns, and whatever means require to be adopted for the purification of the sewage of the latter before discharge, apply with nearly equal force to the case of the midden towns, whose sewage is to a great extent free from the solid fæces.

Neither need there be any question of increasing the capacity of the sewers of a midden town which has adopted water-closets.

Sewers, as originally laid, were intended principally to carry off the rain and surface waters from roofs, yards, and streets, and their size was entirely regulated by the volume of these waters which they might be called upon to receive at any time, such as during heavy storms of rain. The sudden rush of water into the sewers during and after a heavy shower far exceeds in volume the maximum daily flow of foul water from the houses with which they are connected. And even were it not so, the entire excreta of a town population, in comparison with the waste water of the population, is only, by volume, as about one to a hundred; whilst the additional water required for flushing water-closets and sewers—though varying with the state of the latter and the habits of the people—could not, in comparison with the total volume of sewage, be called large.

The water-carriage system, then, in the simplest way possible renders unnecessary the difficulties and dangers which are inherent to the conservancy systems, and its adoption in towns only demands the greater perfection of sanitary works (sewers and drains) which are already necessary, and in most cases already exist.

Water carriage is, of course, not possible under all circumstances; towns which have a very inadequate water supply may not be able to afford the increased amount of water required to flush water-closets, drains, and sewers, and keep them in good condition. Or, again, towns standing at a very low level may be unable to secure the gradients required to lay a system of gravitating sewers to a possible or desirable outfall. In this latter case, however, the erection of pumping machinery actuated by steam or compressed air is usually capable of solving the problem.

SEWERS

As before stated, sewers in this country were originally designed to carry off rainfall and surface waters. At a somewhat later period the drains from houses were connected with them, so that they received in addition the house waste waters; and in some cases the overflow-pipes from midden pits and cesspools were also carried into them, by which means they received an accession of foul and putrid liquids, often mingled with ashes, which tended to choke them with sediment of a most offensive character. Still more recently in many towns these sewers have also become the receptacles for the water-closet sewage of numerous houses. This subsequent usage not

being in any way warranted by their original design, which was to carry off water *pur et simple*, it is not surprising that they fail to perform the functions now allotted to them, and are in many instances the sources of nuisance and injury to health from causes which we shall presently indicate.

As originally constructed in various towns in this country, the sewers were laid at considerable depths below the surface, and were made of brick. In shape they were rectangular (fig. 176), or with arched roof instead of flat top, but some were circular or oval. At various points, catchpits from the roadway delivered into them, and at convenient spots they discharged into a stream, river, or ditch. Being constructed of porous bricks, they admitted subsoil water, and thus had considerable effect in securing the drainage and drying of the soil. No great stress was laid upon their having good gradients, as they were only intended for rain water, and, being usually of considerable size, there was no difficulty anticipated in removing by manual labour such sediment as might collect in them.

Used in this manner as channels for water containing but few solids in

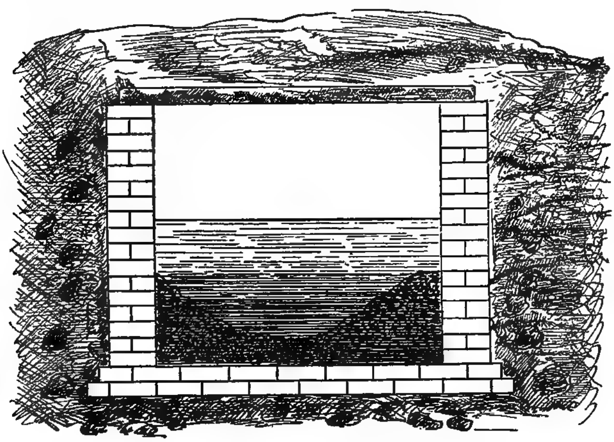


Fig. 176.—Brick square sewer with stone top.

suspension, these sewer drains acted fairly efficiently. Their effect in lowering the level of the subsoil water and drying the ground beneath and around houses was an especially important one. Those diseases which are associated with dampness and moisture of the soil—ague, rheumatism, bronchitis, &c.—have been considerably lessened by works of drainage; but the great reduction in the death-rate from phthisis resulting from the subsoil drainage of those towns which formerly were situated upon waterlogged or moisture-laden soils, was a result as satisfactory as it was unlooked for. In some towns where the sewerage works have caused a considerable fall in level of the subsoil water, which formerly stood within a very few feet of the surface, the deaths from phthisis have even been reduced by a third, and in one case by a half, of what they had previously been.

The great disadvantages, however, attending pervious sewers soon became realised when they became the recipients of the foul waters and excretal refuse from houses. Wherever the gradients of the sewers were insufficient for a proper flow, or where the invert of a portion of a sewer had sunk below its original level, owing to faulty workmanship or want of a proper foundation, the stagnant sewage deposited its suspended particles, and accumulations of

offensive sediment were the result. Owing to the porosity of the bricks much of the water percolated through the walls of the sewers to pollute the subsoil water and contaminate the ground air; and this escape of the water, by withdrawing the vehicle in which the solids of the sewage ought to have been suspended, tended to aggravate the deposit of the latter on the floor of the sewer, and often resulted in its complete choking and obstruction. Manual labour had to be employed to clear the sewers and remove from them the accumulated deposits. Great expense was thereby incurred, and the foul condition of the sewers was often a source of considerable danger to the men engaged in this scavenging work. The foul gases, too, generated by the putrid sediment and stagnant pools of sewage, escaped through the street ventilators—if there were any—or else found their way into houses through drain connections and trapped or untrapped openings.

The pollution of the subsoil with the foul liquids that percolated through the walls of the sewers resulted in contamination of the water in neighbouring wells, and in some cases the water supply of an entire community has been endangered by the entrance of such foul matters into the water mains during intermissions in the service.

In some towns the old drain-sewers still perform the double function of draining the subsoil and conveying away the surface waters and sewage. In these places the evils described as inseparable from defective sewers are always present in a greater or lesser degree. Foul sewer emanations into the streets and houses, polluted wells, and contaminated ground air, exercise a pernicious influence on the health of the inhabitants, and such diseases as enteric fever, diarrhœa, and diphtheria tend to become endemic and to exhibit epidemic outbursts during favourable seasons.

In many towns, however, in this country the old defective drain-sewers have been largely reconstructed of proper materials and of proper size, shape, and fall, but still receive as before both storm waters and sewage on what is known as the *combined system* (*tout à l'égout*). In other towns, again, new pipe sewers have been laid to receive the house waste waters and water-closet sewage, whilst the old drain sewers still perform their original functions as dryers of the subsoil and carriers of rain water. This has been termed the *separate system* of sewerage, and was first prominently brought into notice in this country by Mr. Menzies. It has since been adopted in the United States by Colonel Waring.

The Combined System

In modern systems of sewerage the chief principles involved are (1) the construction of sewers with impermeable materials, so as to prevent, or very greatly limit, the percolation of polluting liquids through their walls into the surrounding soil; (2) the rendering of the sewers self-cleansing by constructing them with sufficient gradients, and of a size suitable to the volume of sewage which they will ordinarily be required to carry; (3) the adoption of effectual means for flushing and ventilating the sewers.

In the construction of brick sewers, well-burnt, tough, impervious bricks should be used; and for the lowest segment, or invert of the sewer, glazed firebricks, or suitably curved stoneware blocks, are found advantageous. The floor or invert of the sewer being the part most liable to wear and erosion from the passage of the suspended matters in the sewage over it, it is highly important that it should be constructed of very smooth, hard, and wear-resisting material. The stoneware invert blocks are occasionally made hollow, and they then provide a means of draining off the subsoil water during the

construction of the sewerage works; but inasmuch as these hollow blocks often lead to settlement of the sewer in sandy soils from sand being washed into them and carried away, and as they are apt to split from the weight of the sewer built over them, they are not now looked upon with favour by engineers. Small sewers under 3 feet in diameter, when laid in good ground, may be constructed of $4\frac{1}{2}$-inch brickwork, but the bricks used should be curved to suit the shape of the sewer when completed. Nine-inch brickwork should be used for larger sewers, or for the small sewers when laid in bad ground or shifting sand. The cement used in jointing the bricks should be a mixture of clean sharp sand and best Portland cement in the proportion of two parts of the former to one of the latter. Portland cement is a mixture of chalk and clay burnt at a high temperature, and subsequently ground very fine. It is stronger and capable of bearing greater tensile strains than other cements, but does not set so rapidly.

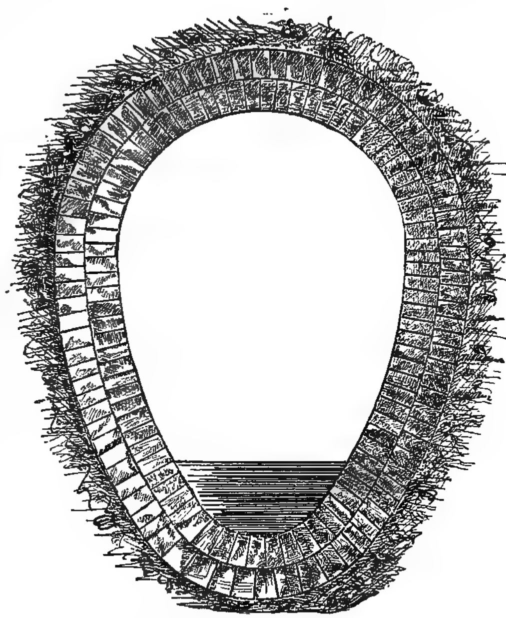


FIG. 177.—Section of egg-shaped brick sewer.

Sewers with an internal diameter over 18 inches are now usually constructed oval or egg-shaped in section, with the smaller end downwards (fig. 177). The volume of sewage flowing through a sewer necessarily undergoes very great fluctuations from day to day, and even from hour to hour. The advantage of the egg-shape is that when the volume of sewage is small, there is a greater depth of liquid and less contact with the walls of the sewer, and consequently less friction, than in any other form. The oval form is also of superior strength to any other form, as it offers greater resistance in every direction to external pressure. There is also considerable economy in the construction of this form. For outfall sewers, however, in which the volume of sewage to be conveyed is large and fairly uniform, Mr. Baldwin Latham advocates the circular form, as being, for these larger sizes, cheaper to build and stronger when constructed.

To render the sewers self-cleansing, and to prevent deposit of sediment on their floors, they must be laid with a sufficient gradient, and must be constructed of a size suitable to the volume of sewage that they will ordinarily be required to carry. Mr. Baldwin Latham advises that sewers of from 12 to 24 inches diameter should have a gradient sufficient to produce a velocity of not less than $2\frac{1}{2}$ feet per second, and in sewers of larger dimensions in no case should the velocity be less than 2 feet per second. A less gradient is required for large sewers than for small sewers to produce the same velocity, but the volume of sewage to be conveyed by the larger sewer must far exceed that to be conveyed by the smaller sewer. Mr. Latham gives the following example in his work on sanitary engineering:—A sewer 10 feet in diameter

having a fall of 2 feet per mile; a sewer 5 feet in diameter having a fall of 4 feet per mile; a sewer 2 feet in diameter having a fall of 10 feet per mile, and a sewer a foot in diameter, with a fall of 20 feet per mile, will all have the same velocity of flow; but the volume of sewage in the 10-foot sewer must be 100 times, in the 5-foot sewer twenty-five times, and in the 2-foot sewer four times, the volume of sewage in the 1-foot sewer.

In practice, however, it is impossible to adjust the size of the sewers on the combined system to the volume of sewage they are ordinarily intended to carry. They must be designed to receive a large portion of the rain falling over the sewered area of a town, as well as the sewage proper from the houses. In most towns a large part of the surface exposed to rainfall consists of impermeable materials—slated or tiled roofs of buildings, paved yards, courts, and streets—so that the fallen rain runs rapidly off the surface to the gutters and street gullies; and it has been estimated that on an average from one-half to three-quarters of the rain falling reaches the sewers within a very few hours, and even more, and in less time, where there are steep gradients.

The sewers, then, have to be constructed of such dimensions as to admit a sudden influx of storm waters in large amount; and in ordinary times of dry weather the volume of sewage conveyed—even the maximum daily flow—may be insufficient to carry along the suspended matters, and a deposit of sediment occurs, which has to be removed by flushing or hand labour.

During heavy thunder showers in this country an inch of rain may occasionally fall in the course of an hour or less. But it is not usual to provide for such heavy storms, which are certainly very exceptional. The usual provision, perhaps, takes account of a quarter of an inch of rain falling in two or three hours. If the provision is insufficient, unless storm-overflows have been constructed, the sewers in low-lying districts become overcharged, and cellars and basements in these low-lying houses are flooded. After a period of drought a sudden heavy storm effectually flushes the sewers, the accumulated sewage deposits are swept away in the rush of water, and finally left behind as a putrid mud on the precincts of the flooded houses. In London the intercepting sewers were designed to receive a quarter of an inch of rain over the whole sewered area of the metropolis in twenty-four hours, and this in addition to the subsoil water ordinarily finding its way into the sewers; but numerous storm-overflows have been constructed, at great cost, direct into the Thames above London Bridge, and these relieve the overcharged sewers during heavy rain, except when their outfalls into the river are tide-locked by a high state of the tide. At such times low-lying districts of the metropolis are liable to be flooded, as indeed happened to parts of the East End of London after the tremendous rainfalls of July, 1888. It is certain also that the discharge of crude sewage into the Thames in the heart of London by these storm-overflows is occasionally productive of considerable nuisance to the river-side inhabitants.

The actual sizes of sewers under the combined system are very various in different towns. In London, in many districts, pipe sewers have now been laid in the smaller streets, the houses of which they connect with a brick sewer in a main thoroughfare. The brick sewers of the smaller streets, courts, and alleys vary in size from 3 ft. by 2 ft. 2 in. to 4 ft. by 2 ft. 2 in. In the larger streets they are from 4 ft. 6 in. by 2 ft. 6 in. to the size of the main sewers, which are of considerably larger but varying dimensions. The three northern outfall sewers are each 9 ft. by 9 ft., with vertical sides. The southern outfall sewer is 11 ft. 6 in. in diameter. Most of the street sewers

and all the mains are large enough for the sewer men to enter and traverse when engaged in removing deposit, in repairing the sewers, or examining house connections.

As previously stated, the large size of the main sewers is necessitated by the immense volumes of storm water they are at times called upon to receive. It has been calculated that a main sewer intended to receive all the sewage of a thickly populated square quarter of a mile, with a water supply of twenty gallons per head daily, and also the rainfall of the same surface, if equally distributed over every day of the year, would only actually require for these purposes a sectional area of 4 square feet, but that practically, in order to provide for sudden storms, this size would have to be at least doubled. A still larger sewer would be necessary for the same population if spread over a larger area.

We have seen that the property possessed by the old pervious sewers of draining the subsoil was a very important one in its bearing upon the public health. Modern brick sewers, being constructed of more impervious materials, necessarily act less efficiently as drains. But inasmuch as it is a matter of great difficulty to make brick sewers quite impervious to water it follows—and such has been proved by experience—that they do to a certain extent admit subsoil water in porous soils, and the sewer trenches also serve as channels for the passage of water alongside the sewers to escape at the sewer outfalls. It is not therefore considered necessary, as a rule, to provide any additional means of draining the soil when brick sewers are in course of construction. Sometimes, however, where there is much subsoil water, a porous pipe drain is laid under the sewer, to carry off water in the soil around it; but when this is done there is a possibility of settlement taking place from sand being washed away in the drain.

In the most modern systems of sewerage the sewers are laid in straight lines, and manholes (fig. 179) are built over the sewer at the points of change of direction. The junctions of the smaller sewers with the larger ones are made at an acute angle, so that the sewage enters the larger sewer from the less in the direction of the flow of sewage in the former. The points of junction, wherever possible, should be above the floor of the larger sewer to prevent backing up of sewage in the smaller conduits, and consequent obstruction to the flow in them.

To calculate the discharge from sewers the following formula is found convenient:—

Let $V =$ velocity of flow in feet per minute.

,, $D =$ hydraulic mean depth.

,, $F =$ fall in feet per mile.

Then $V = 55\ (\sqrt{D \times 2F})$.

If $A =$ sectional area or the current of fluid, $V \times A =$ discharge in cubic feet per minute.

The hydraulic mean depth in sewers of any section is the sectional area of the current of fluid divided by the wetted perimeter (that part of the circumference of the sewer wetted by the fluid flowing through it); in circular sewers it is constant and equal to one-fourth the diameter.

The Separate System

In this system the house sewage is separated from rain and surface waters and conveyed away in pipe sewers of small diameter. The pipes (fig. 178) need be only of small size, for they are not liable to any sudden influx of

storm water, and the daily volume of house sewage—even its hourly variations—can be calculated with some approach to accuracy from the water supply and known habits of the population. In small towns the pipes usually vary in size from 6 in. to 15 in. in diameter, the smaller pipes receiving the house sewage in the bye-streets, and the larger being collecting pipes conducting the sewage to the outfall sewer. Some authorities advise that no public street sewer should be less than 9 in. in diameter, owing to the risk of smaller pipes becoming obstructed by articles improperly introduced into the house drains; but in actual practice we believe it to be very rare for such stoppages to take place in pipes of 6 in. diameter.

Up to 18 in. internal diameter sewers should certainly be circular in section; and for these small sizes pipes of stoneware, cement, or concrete are preferable to brick sewers. In this country glazed stoneware pipes are most generally used for the sewers of the separate system; but in Germany cement and silicated concrete pipes have been extensively used. Mr. Baldwin Latham describes these pipes as being less brittle, more capable of withstanding extremes of climate, and of resisting the chemical action of the sewage than stoneware pipes. They are also said to improve materially with age, and to be unaffected by the jar and vibration of heavy traffic in the streets overhead, which sometimes causes stoneware pipes to split. Like stoneware, pipes of cement or silicated concrete are impermeable to water when properly jointed.

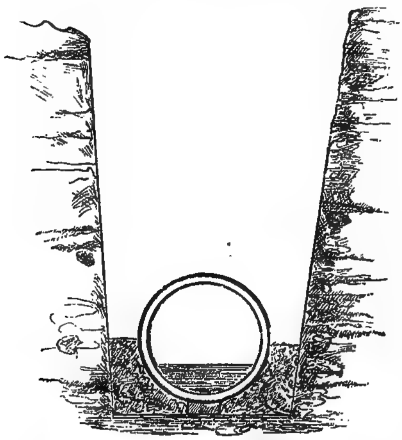


FIG. 178.—Pipe sewer in trench.

As for house drains, so stoneware pipes intended for sewers should be laid on a firm bed of hard ground or cement concrete at gradients sufficient to give a velocity of flow of $2\frac{1}{2}$ or 3 feet per second, according to the diameter of the pipes. The socket end of the pipe should be placed upwards and the joint between the spigot end of the pipe above and the socket of the pipe below should be filled in with the best Portland cement, especial care being taken to remove any cement projecting from the interior of the joint into the pipe, which, when hardened, would form an obstruction to the flow of sewage through it. The junctions between pipe sewers should be made by means of properly curved junction pipes; and where one or more tributary sewers join a main sewer, a manhole (fig. 179) should be built over the point of connection, with curved channels in its floor for the connecting pipes.

When pipe sewers are laid in loose sandy soils it often happens that subsoil water gets into them, and issues from their mouths as soon as they are laid, in consequence of the cement, even when covered with a clay lute, getting washed into the sewers before it has time to set. If this happens the sewers are not impermeable, and whilst subsoil water finds its way in, foul liquids may percolate out into the surrounding soil. In these bad soils cast-iron pipes may be laid with joints made with red lead, cement, and spun yarn, or better with molten lead; or in the case of stoneware pipes Brooke's subsoil drain and pipe rest may be used. This subsoil drain and pipe rest has the form of the letter ⌂; it is laid in the bottom of the trench, like an ordinary pipe sewer, and jointed with clay, and has the effect of lowering the subsoil

water, so that the sewer proper can be laid upon the movable saddles or rests, undisturbed by water or running sand. By these means the cement joints can be made perfect all round, and have time to set before the trench is filled up. True gradients are ensured, as the pipes can be leisurely laid; and as the pipes are jointed over the middle of the subsoil drain a continuous foundation is secured. A more perfect drainage of the subsoil is also found to result, the general level of the water being reduced to nearly the level of the sewer invert.

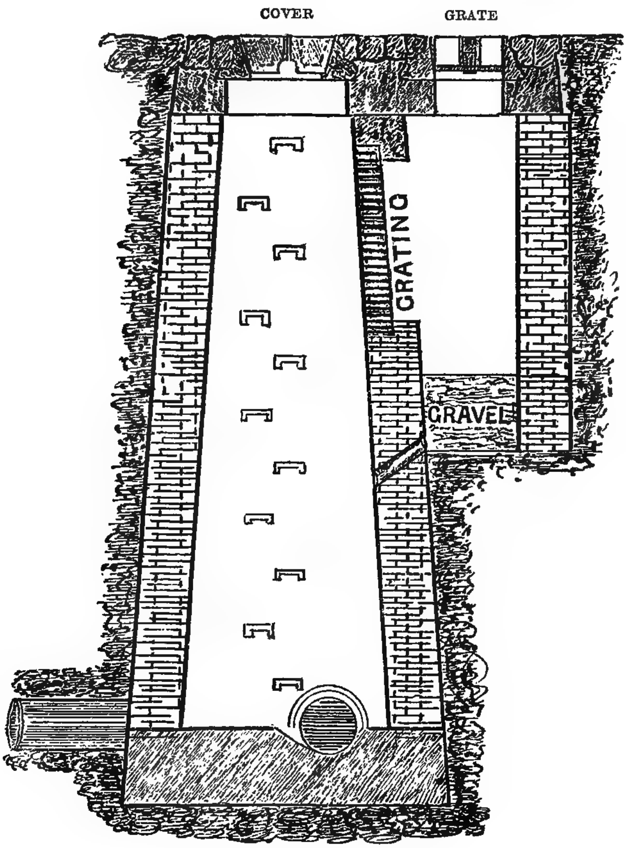


FIG. 179.—Manhole and ventilator.

The only sewers with the separate system which need be of brickwork are the large mains and outfall in good-sized towns and the outfall sewer in the smaller towns.

The pipe sewers receive the water-closet sewage and waste waters of houses only. The rain water from the roofs and yards of houses must be conveyed by separate pipes into surface channels at the sides of the streets, when the gradients are sufficient, or into underground channels constituting a system of drains quite distinct from the sewers. In many towns the old existing brick drains have been utilised for the latter purpose, and they also serve as subsoil drains. At convenient points the surface channels or underground drains should discharge into the stream or river which constitutes the natural drainage bed of the locality.

Where no brick drains exist there is little or no drainage of the subsoil, as the pipe sewers are impermeable to water. In these cases agricultural

tile drains, 1 to 3 inches in diameter with open joints, should be laid in the same trench but above the pipe sewers—which are embedded in clay puddle (Baldwin Latham)—and surrounded with coarse gravel to allow the subsoil water to permeate into them; at suitable points these drain pipes may be diverted into the watercourses.

The advantages of the separate system may be summed up as follows:—(1) The whole volume of sewage to be conveyed away from the town is very much less than that to be dealt with by the combined system. In an instructive comparison of the town of Slough, which is sewered on the separate system, with that of Romford, sewered on the combined system, Mr. R. F. Grantham has shown that the average amount of sewage pumped in a year on to the Slough sewage farm was 30,000,000 gallons, whilst the average amount of a year's sewage received at the Romford sewage farm was over 100,000,000 gallons, Slough having a population of 5,200, with a water supply of ten gallons per head daily, and Romford a population of 5,300, with the same amount of water supply.

(2) The daily and seasonal fluctuations in the volumes of sewage delivered under the separate system are small, and the total quantities to be dealt with can be approximately calculated from the population and water supply, these being points of the greatest practical importance where the sewage has to be pumped at the outfall or purified before being discharged. The daily and weekly fluctuations under the combined system may be enormous owing to the entry of rain and subsoil water into the sewers. Thus at Romford, during a period of three years, the largest amount of sewage received in the course of a week at the sewage farm was 3,662,000 gallons, and the smallest amount representing the dry weather flow only 1,321,000 gallons—equal to about one-third of the greatest.

(3) On the other hand, on the separate system, the sewage of every twenty-four hours is fairly uniform in composition, because it is protected from dilution with storm waters, and its purification and utilisation are undertaken with much less difficulty than in the case of sewage varying in strength according to the amount of rain and subsoil water mixed with it.

(4) The sewers, too, being of small size and having perfectly smooth walls, are more often running full, and are therefore better flushed, with less tendency to deposit sediment resulting in the formation of foul gases, than is the case with the large brick sewers, to whose walls foul matters so readily adhere.

(5) Lastly, the cost of the system is very much less than that of the combined system. Pipe sewers are more quickly laid than brick sewers can be built; they require a much smaller amount of excavation than brick sewers, and they can be made with very various curves to suit different positions.

The disadvantages of the separate system are, that every house must be provided with two drains, or two sets of pipes—one for sewage and the other for rain water. This means a somewhat heavy initial outlay on the part of houseowners, and it occasionally gives rise to mistakes on the part of builders, who connect the pipes with the wrong system. The surface water from yards and streets is also sometimes foul, especially when a storm succeeds a period of drought, and this foul water may conceivably cause a nuisance in the stream into which it is discharged. At Slough, however, no complaint has ever been made about the surface-water drain, which discharges into a ditch by the side of a public road within the statutory three miles distance from the river Thames, and therefore within the jurisdiction of the Thames Conservancy. It has been recommended that the surface water

from the back yards of houses should be discharged into the sewers, instead of into the surface channels or subsoil drains, as these waters are often of a somewhat polluting nature. But it would probably be better for the local authorities to enforce proper scavenging and cleansing of the yards and streets than to introduce storm waters into pipes of size possibly inadequate for their reception.

Numerous towns in this country are now provided with pipe sewers, and the system is likely to be much more largely adopted in all cases where circumstances are favourable to its execution. In America, the city of Memphis has been sewered on the separate system, the plans of the works being designed and carried into execution under the direction of Colonel Waring. A very complete and interesting account of the system and its working at Memphis will be found in the Second Annual Report of the State Board of Health, New York, 1882. Pullman, near Chicago, is also sewered on the same system, and numerous other towns in the States propose to adopt similar works.

Flushing and Inspection of Sewers

In the old badly constructed brick sewers, without sufficient incline, large deposits of semi-solid filth took place, which were removed by hand labour at great expense. In some cases the deposit was removed through manhole entrances to the sewers, but in others where it was 3 or even 4 ft. thick, and had stopped up the sewer, not only had the street to be broken up, but the arch of the sewer was also broken into, and the foul mud raised to the surface and carted away, the whole process causing a very great nuisance to the neighbourhood. The late Sir Joseph Bazalgette in his work on the 'Main Drainage of London' has stated that the cost of removing deposits from the tide-locked and stagnant sewers in London formerly amounted to about 30,000*l.* per annum.

It soon, however, came to be understood that periodical flushing of the sewers was able to accomplish this work of carrying away sediment in a far more efficient and economical manner than removal by hand labour. By heading up the sewage in a certain spot, by means of sluices or flushing gates made to fit the greater part of the sectional area of the sewer, a force sufficient to effectually flush and cleanse the sewer below for a considerable distance can be generated on raising or liberating the gate.

These flushing gates can be fixed at the sites of manholes, and can then be manipulated by the sewer men, or self-acting gates can be used for the same purpose. In this form the gate is fixed in the sewer by hinges attached below its centre. The pressure of the sewage on that portion of the gate which is below the hinge fixes it in position, and the sewage rises until it reaches the upper portion of the gate. This presents a larger surface to the dammed-up sewage than the lower portion of the gate below the hinges, so that a point is at length reached when the gate tilts forwards, assuming a horizontal position, and the sewage escapes with a velocity proportional to its head.

These gates are of course inapplicable to the upper or dead ends of brick sewers. Perhaps the best method of flushing these and the smaller tributary sewers is to discharge the contents of a street watering cart suddenly into a manhole or other opening into the sewer.

Sewers are most in need of flushing during the summer season and prolonged periods of dry weather. At these times, unless artificial flushing is

resorted to, the amount of water flowing through the sewers is insufficient to prevent the deposit of sediment. But the flushing should be periodical in the older brick sewers all the year round, for, although heavy rainfall is very effectual for flushing purposes, it cannot be depended upon in this climate to occur at properly recurring intervals, and it introduces, besides, a quantity of sand and grit from the surfaces of the roads which tends to settle in depressed portions of the floors of the sewers, and to form the nidus for further deposits of sediment.

It is certainly advisable that arrangements should be made for flushing the pipe sewers of the separate system, inasmuch as they do not experience the cleansing effect of storm waters, in all cases except where the gradients are very good and the water allotted for closet-flushing purposes is ample. Perhaps the best method is that introduced by Colonel Waring in the case of the pipe sewers at Memphis. At the dead end of every branch sewer is placed an automatic siphon flush tank with a capacity of 112 gallons. The tank consists of a brick chamber, built on a concrete bottom, set below the level of the street and covered with a perforated lid; in the centre of the tank is an annular siphon (fig. 185, p. 888) which discharges into a box underneath it, and thence into the sewer. The tanks are filled from the city water supply, and discharge their contents with the most perfect regularity. The rush of water from them is distinctly felt at a distance varying from 400 to 900 ft., keeping the pipes perfectly clean. No tendency to freeze has been noticed in the tanks, although the temperature of the air has been as low as 4° F. In all, there are 125 of these flush tanks at work in Memphis to flush twenty miles of sewers. A slight deposit of silt has at times occurred in some of the mains, but this has never been more than 1 or $1\frac{1}{2}$ inches in depth.

Means of access must be provided for brick sewers—for their examination, for the execution of necessary repairs, and for their cleansing. For this purpose manhole shafts (fig. 179) are sunk from the surface of the road to the sewer by which the scavengers can descend. They are constructed of brickwork and provided with a locked iron door at the street level. In streets with much traffic the shaft is sunk from the footway perpendicularly for a sufficient distance and then carried down by means of steps to the side of the sewer. In unfrequented thoroughfares the manholes may be sunk from the roadway direct to the crown of the sewer or immediately at its side. The side entrances are not so cleanly as those opening into the crown of the sewer, as in times of heavy rain the sewage may leave detritus on the steps of the passage, which subsequently decomposes and gives rise to offensive effluvia.

The manholes have also other uses; they serve as points of junction between tributary sewers and the main sewers, and they are the points at which flushing gates and ventilators may most advantageouly be fixed.

In the pipe system of sewerage manholes should be constructed on the mains at convenient points, such as where a change of direction occurs (fig. 179). At Memphis there is a manhole at a distance of every 500 ft. on the mains. On the branch sewers T-pieces should be inserted at intervals, with a lid on the top of the upright stem at the street level, which can readily be removed, and a cleaning tool introduced to clear away the obstructions which are occasionally produced by the introduction of improper articles into the house drains. At Memphis several 2-foot carpenters' rules, folded to 6 inches, which had passed through the 4-inch traps on the house-drains, have been removed from the 6-inch pipe sewers after causing an obstruction to the flow of sewage through them.

Ventilation of Sewers

Considerations arising from the facts elicited by modern research into the causation and propagation of infectious diseases have imparted an importance and significance to the subject of sewer ventilation which was absent in times but recently passed. To know that the infective agents of such diseases as cholera, typhoid fever, many cases of diarrhœa, and probably other diseases, are passed out of the body in the excretions of the patients suffering from them, that they probably have the power of self-multiplication outside the body in sewers and sewer deposits, and can infect the air in contact with them, is to understand the importance which sewer ventilation has on the public health, and to impress the necessity for the closest attention to this subject on the part of those who are entrusted with local sanitary administration.

In the first place, we see that town sewers are underground channels, which place houses both near and remote from one another in more or less direct aërial connection in all cases except where the house drains are disconnected from the sewer by a water trap and an opening to the external air on the house side of the trap. Between houses where this form of disconnection is not practised, not only is there the aërial connection, but rats and other vermin may be the means of carrying infected filth from a fever-stricken house to a healthy one. This latter mode of conveying contagion has, however, been more fully treated of in the chapter on house drainage, and does not require consideration here. It is sufficient for us here to know that the poisonous agents of disease excreted in one house may be wafted in the air of the sewers into the drainage pipes of another house in its neighbourhood, or even remote from it. To counteract this mode of propagation of disease, two precautions are essential. The first is to prevent by means of water-traps and a proper system of house-drain ventilation any entrance of drain or sewer air into houses; the second is the adoption by local authorities of some means whereby an abundance of fresh air can be introduced into the sewers, and the mixed air and gases can escape from the sewers at points as remote as possible from inhabited dwellings. As in house drains, so in sewers, a constant current of fresh air should be flowing through them to dilute the offensive gases and render less dangerous the disease poisons which may possibly be present, and this current very effectually aids the escape of the sewer air at the proper points of exit.

It is now generally believed that the bowel discharges in cases of typhoid fever and allied diseases may impart their infective qualities to large volumes of sewage, and to the deposits and slime which are so frequently found on the floors and walls of sewers. The microbes of such diseases find a suitable soil for growth and multiplication in sewage and sewer deposits, which, it must be remembered, are always considerably warmer than the outer atmosphere during the winter months, and contain organic matters of both animal and vegetable origin, phosphates, nitrates, and ammonia, all affording food for the growth of micro-organisms. There is plenty of evidence to show that the percolation of infected sewage out of sewers into wells and water mains has produced epidemic outbursts of fever; and there can be but little doubt that the sewer air in contact with such infected materials also becomes imbued with specifically contagious properties. For enteric fever has undoubtedly been caused by inhalation of sewer air, no other means being ascertainable by which the infected persons could have been brought into contact with contagion; and there are the records of specific contamination of drinking water in cisterns and mains by such air.

Amongst other diseases of which proof has been adduced that they are occasionally the result of sewer-air pollution may be mentioned a severe form of acute tonsillitis (sewer-air throat), diphtheria, and the hospital fevers—surgical fever, erysipelas, pyæmia, septicæmia, and puerperal fever. Years ago these diseases were very constantly present in the wards of general and lying-in hospitals; but since measures have been taken to improve the drainage of these institutions and prevent any possibility of foul air gaining access to the wards, such diseases have greatly diminished, or even totally disappeared.

As regards chemical composition, sewer air varies very widely. In modern well-ventilated sewers the air is by no means foul. Samples collected by Dr. W. J. Russell from the metropolitan sewers in the Paddington district during the month of August, 1869, were found to contain 0·51 volume of carbonic acid, 20·7 of oxygen, and 78·79 of nitrogen in 100 volumes. In so far as these constituents are concerned, the impurity is not great, and in no way accounts for the injurious properties of sewer air.

In the old-fashioned brick sewers, where sediment collects, the gaseous impurity is often excessive. Brick conduits with flat bottoms (fig. 176), circular or oval sewers in which a portion of the invert has sunk below its proper level, and sewers which are too large for the volume of sewage they ordinarily convey, are all liable to deposits of sediment on their floors or sides, which can only be removed by artificial flushing. The bacterial agents of putrefaction present in all sewers attack the sediment, and cause a fermentation productive of the evolution of such foul gases as sulphuretted hydrogen, ammonium sulphide, and carbon disulphide. Some of the other fœtid gases given off during the putrefactive process are highly complex bodies, probably carbo-ammoniacal and allied in chemical constitution to the compound ammonias—methylamine and ethylamine. These have a highly offensive odour. Organic vapours of unknown constitution are also evolved, and amongst these may occasionally be found traces of the animal alkaloidal substances—ptomaines and leucomaines—which are contained in the fæcal and urinary excretions of the animal body, and exert a directly poisonous action on the system. Free ammonia is also given off to a slight degree by putrefying sewage, and is derived from fermentation of the urea of urine—a molecule of urea taking up two molecules of water to become carbonate of ammonium. Of innocuous gases given off, the chief are carbonic acid, nitrogen, and carburetted hydrogen.

Of late much attention has been directed to the organised constituents of sewer air—to the microbes (bacteria and moulds with their spores). By the method of plate cultivation of the microbial colonies on solid nutrient media it is now possible to estimate the number of micro-organisms or their spores present in a measured volume of sewer air, which are capable of growing in these media at temperatures below that at which the solid medium liquefies. Observations made by this method in this country tend to show that sewer air, taken from sewers in which fermentative processes are in abeyance, is remarkably free from all such microbes. The microbes remain in the sewage, and are not given off to the air in contact with it, or if they are, there is reason to believe that they quickly adhere to the moist internal walls of the sewer, and are thus prevented from floating far. That such is the explanation is rendered more certain by what is already known of the presence of microbes in the outer atmosphere, for during dry or dusty weather they are found in far larger numbers than during or after rainfall.

These experiments have been made on the air of sewers, in which the

sewage is carried away in a fairly fresh and undecomposed condition. But we believe that no extended observations have yet been made on the air of those sewers where accumulations of putrefying sediment are to be found. In such cases we are inclined to believe that the sewer air contains floating in it an excessive number of microbes and spores. In the first place, there is the almost universal domestic experience that meat, milk, and other organic substances rapidly taint and putrefy when exposed to drain or sewer emanations, and this points strongly to the presence of the bacterial agents of putrefaction in such air; and, secondly, it was demonstrated, as long ago as 1871 by Professor Frankland, that, although liquids flowing smoothly in channels give off no solid particles to the air, and that even considerable agitation resulting in frothing may not cause any perceptible increase of the solid particles in the superincumbent air, yet the bursting of bubbles of gas in a liquid had a marked effect in disseminating solid particles. The bursting of bubbles of gas on the surface of a liquid is an invariable accompaniment of the fermentative processes which take place in stagnant sewage and sewage deposits, so that there can now be little doubt but that the air in contact with putrefying sewage is loaded with micro-organisms of different kinds. Frankland's conclusions, too, have been practically confirmed by the experiments of other and later observers.

And, after all, it is not so much a question of the quantity of bacterial organisms present in sewer air as of the quality of those that do exist, whether large or small in number. The fallacy of reasoning that, because sewer air under ordinary conditions contains but few demonstrable organisms it must *ipso facto* be innocuous, is sufficiently obvious to require no refutation. Too little is known at present about the microbes present in sewers to warrant dogmatic assertions of any kind, but it is believed that the large majority are harmless or at least non-pathogenic. Others there may be, present at times only, and then, perhaps, not in company with a crowd of harmless species, which are productive of those varieties of illness in the human subject that are known to result from sewer-air poisoning. The history of sanitation in this country, too, tends conclusively to show that improvements in sewerage and house drainage, whereby sewer air is excluded from houses and dispersed harmlessly in the external atmosphere, have had a most beneficial effect upon the public health in the reduction of the prevalence and mortality from typhoid fever and the other filth diseases.

The injurious effects attributable to the inhalation of sewer air may for convenience be divided into those produced by the foul inorganic gases, and those resulting from the organic vapours or the organised constituents of such air. Under the first head must probably be classed those cases of complete or partial asphyxia which formerly occurred amongst the Paris scavengers when engaged in removing deposit from choked sewers, or in emptying and cleansing cesspools and privies. These asphyxial symptoms (*le plomb*) were either caused by excessive disengagement of sulphuretted hydrogen gas, when the contents of the sewers or cesspools were stirred up, or were due to the very low proportionate volume of oxygen existing in the air, or to both of these causes combined. Thus Parent Duchatelet found the air of a choked sewer in Paris to contain nearly 3 per cent. of sulphuretted hydrogen, and only 13·8 per cent. of oxygen.

Cases of acute mephitic poisoning have been recorded amongst scavengers employed in cleansing foul drains and sewers, the symptoms being sudden and violent vomiting, purging, and headache, followed shortly by acute prostration, sometimes ending fatally. These symptoms are probably as much

due to inhalation of foul organic vapours as to the inorganic compounds of sulphur or ammonia.

At the present day, owing to the improved construction of sewers and their better ventilation, such cases of asphyxia or acute poisoning amongst the sewer men are very rare. As a rule, these men appear to enjoy very fair health, no doubt because their work is now conducted in a relatively pure atmosphere. But it must be remembered that they are picked men in the prime of life, for only those continue at the work who find no injury to health arising from it; probably many men give it up after a short trial, as being unsuited to their constitutions. It has also been stated that sewer men, as a class, suffer somewhat from ophthalmia and headaches, and that the occupation tends greatly to aggravate venereal disease (Parent Duchatelet). It seems fair to assume now, in the light of our present knowledge, that the men engaged in this occupation undergo a species of preventive inoculation or acclimatisation, so to speak, to the influences to which they are exposed. The long-continued inhalation or ingestion of a germ-tainted air may be considered as conferring immunity upon the individual from filth diseases which would readily attack one whose system had not been exposed to the acclimatising process.

The contamination of the air of houses with sewer or drain emanations appears to be productive in many instances of loss of health amongst the occupants, more especially in those cases where the escape of sewer air is continued for long periods. The dose of the poisonous atmosphere may not be sufficiently great at any one time to cause those acute and dangerous illnesses before mentioned, but a condition of ill-health is engendered, especially in children, shown in various ways, as by loss of appetite, prostration, diarrhœa, anæmia, headache, vomiting, sore throat, and fever. One or more of these symptoms predominate over the rest, according to the season of the year and the idiosyncrasies of the individual. Dr. George Johnson has described cases of albuminuria and destructive kidney disease as being the result of long-continued sewer-air inhalation. Whether rendered seriously ill or not, a condition of depressed vitality is certainly a marked characteristic of the inmates of a badly drained house.

It is now generally believed that these symptoms of illness are due to the entrance into the body of the organic matters present in the sewer air; and modern views regard the micro-organisms, which constitute a certain proportion of these organic matters, as being the poisoning agents rather than the gases and vapours, however complex in their chemical constitution. Whether these microbes should be classed as pathogenic organisms, or whether they are to be regarded as the ordinary bacteria of putrefaction and fermentation, which on entrance into the body pervert the healthy action of the tissues, causing diseased processes, is a problem the solution of which is not yet reached.

It now becomes necessary to inquire into the causes which produce movements of air in the sewers, for only upon a proper understanding of this subject can any system of efficient sewer ventilation be founded. The most important of these causes are: (1) a strong and rapid stream of sewage tends to create a current of air in the sewer in the same direction as the flow of sewage, and of proportionate velocity. Under such circumstances many of the street openings into the sewers become inlets for fresh air, which travels with the current of sewage and finally escapes at the sewer outfall. (2) As the volume of sewage increases air is expelled from the sewer, to again find its way in when the volume of sewage diminishes. As a rule, the quantity of sewage passing down a sewer steadily increases from

the early morning hours up to noon, and in the afternoon as gradually diminishes, until at night in brick sewers little but subsoil water is being conveyed. It follows, then, that in the morning air is being slowly expelled from the sewers, whilst for the rest of the day the reverse action takes place. The sudden influx of a large quantity of storm water into a sewer causes a very appreciable expulsion of air; but this is, to a certain extent, counterbalanced by the aspirating effect of the current of air in the direction of the flow of sewage. The rising of the tide in an outfall sewer unprotected by a tidal valve also causes expulsion of air, but the displacement is so gradual as to be almost inappreciable, owing to the slowness with which the water rises and the innumerable channels permeable to air by which the interior of a brick sewer communicates with the exterior. (3) During the colder months of the year the temperature within a sewer is, owing to the warmth of the sewage, considerably higher (averaging about 7° F.) than that of the outer atmosphere; consequently the warmer sewer air tends to rise and be replaced by the colder air from above. In the summer months the day temperature of the sewer is often below that of the external air, and the interchange between the sewer air and the outer atmosphere is reduced to a minimum. In the spring and autumn months the temperatures inside and outside tend to approximate. (4) The discharge of large volumes of hot liquids from houses and factories, and the practice of blowing off steam from boilers into the sewers, causes heating and expansion of the sewer air and its rapid expulsion through the nearest sewer openings. This more especially follows the blowing off of steam, and sometimes, when the sewers are insufficiently ventilated, results in the forcing of the traps on house drains and pipes, and the escape of the foul air into the interiors of houses. There is also the objection to the introduction of hot liquids or steam into sewers that the decomposition of the sewage is accelerated by the high temperature to which it is raised, and that, in consequence of the saturated condition of the air and its high temperature, the sewer cannot be entered until it has been opened to the air for some time by means of the manholes, and thus a difficulty is placed in the way of frequent inspection. (5) Sudden changes of barometrical pressure and of external temperature cause corresponding variations in pressure within the sewer, resulting in the passage of air, as the case may be, into or out of the sewer.

If the sewers have no ventilation openings, or if, for any reason, these have become choked or stopped up, the air within, from the causes above mentioned, will find its way out through defective joints on house drains or soil pipes, through bell-traps in floors or on waste pipes, into the interiors of houses in all those cases where there is no disconnection trap on the house drain; and these escapes of sewer air tend to become aggravated by the aspirating effect of fires and the warmth of inhabited houses on the colder air contained in the drain and soil pipes. In houses of this class the rain-water pipes from the roof, being directly connected with the house drain and sewer, without the intervention of a trap, may act as sewer ventilators. But such a plan is a dangerous one, as these pipes are usually very loosely jointed, and the air rising from the sewer will escape through every such joint, possibly into bedrooms; and in many cases the open head of the pipe is just beneath a dormer or attic window. During heavy rain, too, the rush of water down these pipes will force the foul air into the interior of the house through trapped or untrapped openings.

The ventilation of sewers by means of the soil-pipe ventilators of houses is equally objectionable, except where the sewers are stoneware pipes laid between the backs of two rows of houses, for then the drains will not pass

under the basements of houses, and the entry of sewer air into the house may be prevented by trapping and disconnecting all waste and overflow pipes, and substituting siphon gullies for bell-traps. But where houses drain into sewers laid in the front road, the drain must pass under the house, and with this method of sewer ventilation there would be constant risk of the escape of sewer air through defective joints into the interior of the house. There is also another objection to this method, which applies to the case of sewers which receive rainfall. During or after heavy rain, when ventilation is most required for affording a safe exit for suddenly displaced sewer air, house drains, or any part of them, are often useless for this purpose, as their openings into the sewer may be sealed by the height at which the mixed sewage and storm water is flowing. This is also a valid objection to the practice of carrying up a ventilating pipe to the roof from the house drain on the sewer side of a disconnecting trap. At ordinary times it may serve as an exit for sewer air, but when its services are most required it is liable to fail.

The simplest method of ventilation, and the only one that is in most cases practicable, is to construct a shaft leading from the crown of the sewer to the surface of the roadway above, the opening at this spot being protected by an iron grid. Immediately below the gratings should be fixed a dirt-box to catch mud and gravel that would otherwise fall into the sewer, a space being left around the box for the passage of air to and from the sewer.

These surface roadway ventilators should be constructed at not greater distances apart than 100 yards—say eighteen to a mile—and where the sewers are flat, or for any reason not self-cleansing, the ventilators should be even nearer together. In the metropolis the average distance apart is 120 yards, and the shafts are circular in shape and about 18 in. in diameter, with a superficial area for ventilation of 254·5 square inches. The openings in the gratings are, however, very much smaller, varying from 27 up to 70 in. of superficial area, and thus the large size of the shafts is rendered absolutely inoperative by the small size of the gratings.

Another plan which is largely adopted is to combine a ventilator with a vertical manhole (fig. 179). A ventilating shaft is sunk for some distance by the side of the manhole, and openings are left between them for the passage of air. Mud and stones falling into the ventilator can be removed through the manhole by the scavenger, but the water is carried by a pipe into the sewer beneath.

Some of these surface ventilators will be found to act as inlets for fresh air, and others as exits for foul air, varying from day to day, and from hour to hour, according to the special circumstances affecting the movements of the sewer air, as previously described. The sewer air escapes towards the centre of the roadway, where it is rapidly diluted with fresh air, with the least chance of offence to foot passengers on the sidewalks, or of finding an entrance into houses through open doors and windows.

Nevertheless, these surface ventilators are often productive of considerable nuisance in hot weather or during periods of drought. The offensive smells that are then perceptible are a warning that a deposit of sediment has taken place in the sewer below, and when this is removed or flushed away the nuisance ceases. There may not, however, be sufficient dilution of the sewer air with fresh air, and then it becomes necessary to increase the number of roadway ventilators, or to supplement their action by constructing shafts 6 in. or more in diameter, leading from the crown of the sewer to the side of the road and thence up houses or buildings, clear away from all windows and chimneys. These shafts, being carried up to a considerable height above the

ground, will act principally as exits for foul air; whilst the surface ventilators will become inlets for fresh air, and nuisance arising from the escape of sewer air in the streets will be to a great extent obviated.

These shafts have proved of great service for ventilating the upper or dead ends of sewers in narrow enclosed courts or streets, where the sewer air escaping from the surface ventilators is not rapidly diluted by fresh air owing to the obstruction offered by surrounding buildings. In these cases considerable collections of foul sewer air, productive of great nuisance and injury to the health of the inmates in the surrounding houses, may occur on calm days.

Pipe ventilation up the sides of the houses should be used to supplement the existing surface roadway ventilation, and not to take its place. For, if used for the latter purpose, the efficiency of the whole sewer ventilation would be greatly impaired by the obstruction offered to the passage of air in these long pipes with their numerous bends and turns. In any case they must be fixed with great care to the houses, and the joints must be made thoroughly secure to avoid any risk of foul air entering houses through windows and chimneys. It is, perhaps, for this reason that local authorities have found so much difficulty in obtaining the consent of house owners to the erection of these shafts against their outer walls.

Street gullies should not be used as sewer ventilators, but should be effectually sealed with water, both to prevent road detritus entering the sewers, and to prevent the escape of sewer exhalations close to the footways and the fronts of houses. In dry weather, street gullies should be periodically recharged with water from a watering cart.

It was formerly the custom to filter the sewer air escaping from the manhole and other surface ventilators through wood charcoal contained in iron-wire baskets; but it soon came to be recognised that the deodorisation of the sewer air lasted only so long as the charcoal was dry, and that when the charcoal became damp—as it very soon did—its pores were clogged, and then it obstructed all passage of air. There can be no doubt that, when dry, wood charcoal has considerable effect in deodorising sewer air by oxidising organic vapours, as is shown by the fact that nitrates and ammoniacal compounds can be recovered from the used charcoal. But when placed in the ventilators it soon becomes wet from rain and moisture, and requires to be recarbonised about once every month or six weeks. For these reasons charcoal filters have now been nearly everywhere discontinued.

Various other plans have from time to time been suggested, with a view to the deodorisation of the sewer air escaping from ventilators by means of chemical gases or solutions of supposed antiseptic properties. And a method of passing all the air so escaping through a ring of gas burners, known as Keeling's Extractor, has also been tried. Here the escaping gases are actually burnt, or at least very highly heated. The same objections apply to all such methods. Their initial cost is large; they require a considerable amount of attention, involving labour and expense; and if they are successful in accomplishing what they are intended to do, viz. the mitigation or prevention of nuisance, they tend to conceal a condition of things in the sewers which is in itself injurious, and which being unknown or unnoticed, fails to receive the proper remedy. They do not, therefore, in any way go to the root of the evil, but gloss it over by getting rid of the chief evidence of its existence.

In sewers laid with steep gradients a current of air tends to pass up from the low to the high levels in the reverse direction to the flow of sewage. This is more especially likely to happen in cold weather, when the sewer air is at a considerably higher temperature than the external atmosphere. The

offensive gases escape at the high levels, and are the subject of very general complaint. The remedy lies in constructing at various points on the sewers of steep gradient a tumbling bay with manhole and ventilator (fig. 180), and with a flap-valve applied to the mouth of the sewer delivering sewage from the higher level. Then the sewer air in its course upwards meeting the flap-valve is forced to escape into the outer air through the ventilator, and so does not reach the higher part of the sewer.

The plan of connecting sewers with the chimneys of furnaces has now been abandoned. The draught up the chimney creates a very strong current of air in the sewer for a short distance, but the effect very rapidly diminishes as the distance increases, for air rushes in from all openings in the neighbourhood to supply the place of that extracted by the furnace. In this way the traps on house drains and pipes are liable to be drawn, and when the furnace is not working foul air may pass back into the houses. There is besides the risk of an explosion from ignition of coal gas which may accidentally find its way into the sewer, as happened in Southwark, where the sewers were connected with the furnaces of soap works.

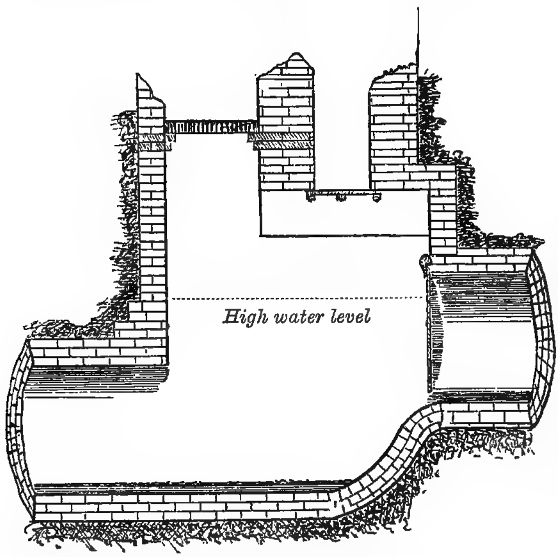


FIG. 180.—Brick sewer with tumbling bay and connection with ventilating manhole.

The ventilation of pipe sewers is a subject which has been carefully considered by Dr. Buchanan in his report upon the epidemic of enteric fever at Croydon in 1875. There is much less tendency to the deposit of sediment in pipe sewers than in brick sewers, owing to the smooth internal walls of the former, and to the frequency with which they are running full or nearly full, so that the whole of the interior is periodically washed. For this reason pipe sewers are but seldom productive of offensive gases. But the air within them, if there are no ventilation openings, is liable to be under far greater pressure than the air in the larger brick sewers, for the reason that the sudden entrance of a volume of water into a sewer of small diameter causes a far greater and more sudden displacement of air than if it entered a large sewer, and that the air so displaced has less chance of escaping, owing to the material of which the sewer is made not being porous. For example, the entrance of a volume of water into a 6-inch pipe sewer will cause a displacement of air sixteen times as great as, and much more sudden than, if the same volume of water entered a 2-foot sewer. The displaced air may be comparatively inoffensive, but, as Sir George Buchanan has shown, offensiveness is no criterion of the infectiveness of sewer air, and, as the Croydon experience proves, the entrance of such air through untrapped drain pipes into houses may be productive of an attack of typhoid fever.

In the pipe system of sewerage, then, adequate ventilation is imperatively needed, and the shafts required for this purpose may be combined with the inspection openings which we have seen to be necessary for the purpose of removing obstructions from the pipes.

Outfall Sewers

Until the passing of the Rivers Pollution Prevention Act, and even to the present day in Dublin and some other large towns, the town sewers took the shortest available course to the banks of the river or stream on which the town was situated, and there discharged each by its own outlet. To prevent pollution of watercourses in the centre of populated districts, it became necessary to construct intercepting sewers of large size to receive the sewage of the tributary sewers. The intercepting sewers were united to form one or more large main outfall sewers, which conveyed the sewage outside the town and conducted it to the works constructed for its purification, or in its crude condition to its outfall into the river, as the case might be.

Outfall sewers discharging into the sea or a tidal river are very frequently a considerable source of nuisance in towns situated at so low a level that the gradients are small, and the sewage is tide-locked for some hours of each tide. A tidal valve at the mouth of the sewer prevents the ingress of sea-water, but the sewage which flows from the town during the tide-locked period has to be stored in the outfall sewer. Here it stagnates, depositing a very copious sediment. The tributary sewers also under such circumstances tend to have sewage backed up into them, and the decomposition of the sediment gives rise to so copious a formation of gases that no amount of ventilation will quite obviate the nuisance.

Until recently sewage engineers did not appear to have realised the importance of preventing sewage stagnation in outfall sewers, and placed too much confidence in the scouring effect of large volumes of liquid with, however, but little head. It is certainly advisable that, in all such cases, tanks should be constructed to receive the sewage delivered by the outfall sewer, which can be subsequently pumped away, or that steam or compressed air-pumping machinery should be utilised to relieve the sewers of their tide-locked sewage.

It sometimes happens that the sewage of a town has to be carried across a valley or river. If the outfall sewer is at too low a level to admit of bridging, it must be carried across by means of an inverted siphon, formed of wrought-iron pipes with riveted flange joints laid in the bed of the river or valley. The sewage must be strained of its larger solid bodies before passing through the siphon, or the siphon must be periodically flushed to get rid of the accumulation of solid matters at its lowest point, resulting eventually in complete choking, an occurrence which usually happens unless the current through is of sufficient velocity to carry all solid matters with it. A ventilating pipe should be attached to the descending arm, to give exit to air under pressure in the siphon, which might prevent its proper action.

The Shone System

This system is intended for use in towns situated on low-lying or very level ground, where the sewage has to be pumped to the outfall, or where the sewers have to be laid with very small gradients. The leading feature of the system is the method of raising the sewage by means of compressed air at such points as are convenient on its course to the outfall.

The air is compressed at a central station, and is then conveyed by 2-inch wrought-iron pipes to the ejectors, situated in chambers below the surface of the streets at different parts of the town (fig. 181). These ejectors receive the sewage from the street sewers, and when full the compressed air is admitted into them by appropriate mechanical arrangements, and the

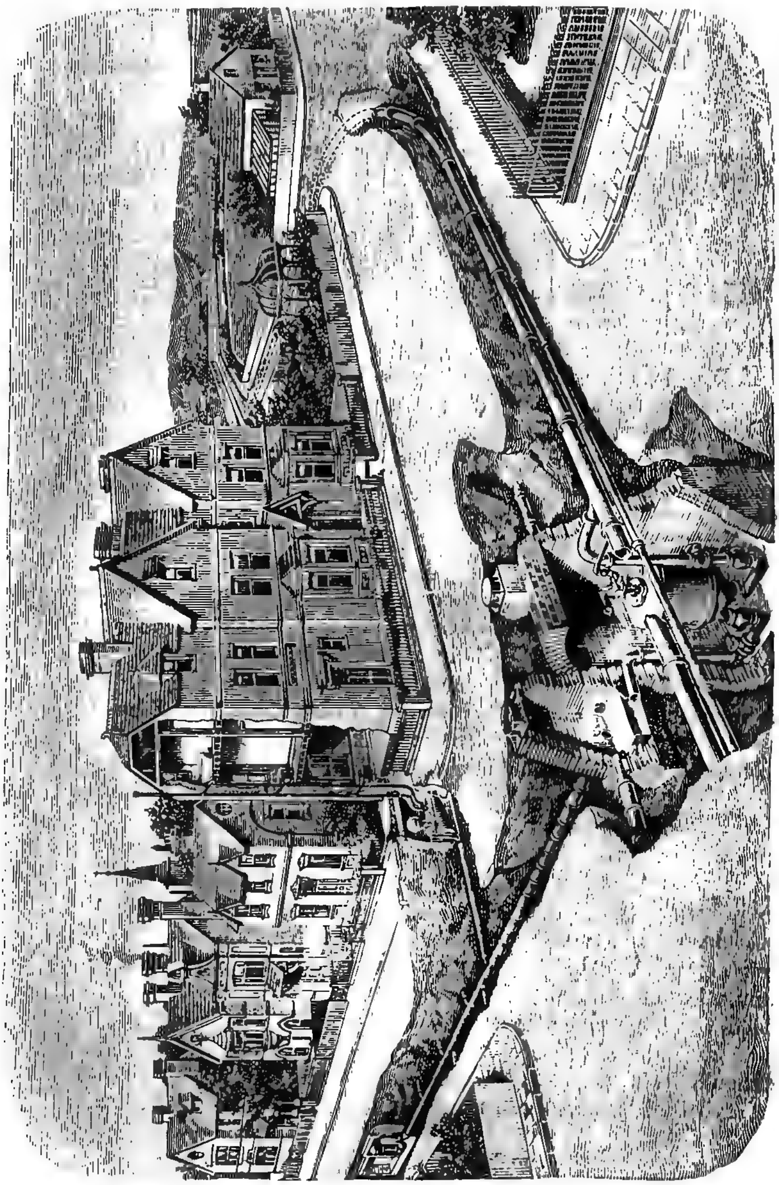


FIG. 181.—Shone's sewage ejector.

sewage is forced out. If the air is compressed to the extent of 15 lb. to the square inch (=one atmosphere) the sewage will be raised to the height of 34 feet in the discharge pipe from the ejector. This discharge pipe is connected with an ordinary gravitating sewer, or the ejector discharges directly into a 'sealed' sewer of cast-iron pipes, when it is necessary that the rise

should be more gradual and continued over a greater distance. The ejectors are placed at a depth below the surface of the ground sufficient to permit of the house drains and street sewers being laid at good gradients, the sewage entering them by gravitation. The ejectors are made of various sizes, depending upon the amount and the maximum rate of flow of the sewage they are required to receive.

The advantages claimed for the system are as follows:—

(1) Good gradients being given to the sewers, the sewage is carried to the ejectors, and forced out of the town, in a fresh and undecomposed state. (2) No storage is required, as in ordinary pumping, where the rate of flow of the sewage may exceed the powers of the machinery; for the rate of working of the ejectors varies with the rate of flow of the sewage, although the rate of working of the machinery for air compression is nearly uniform. (3) Compressed air is a motor that can be conveyed and divided amongst any number of stations near to or far apart from each other without any appreciable loss either by leakage in the pipes, if properly laid and jointed, or by friction, the only loss being that due to clearance of compressed air from the ejectors when discharged. (4) The air can be compressed at one station, so that one staff only is required, as in the case of a single outfall. (5) The temperature of the compressed air is very nearly the same as that of the outside atmosphere, so that, as compared with steam, there is no loss of heat by radiation from the pipes conveying it.

Shone's system has been adopted at Eastbourne, Wrexham, Southampton, Warrington, Henley-on-Thames, and at the Houses of Parliament, Westminster. It certainly seems well adapted for those places in which absence of proper gradients causes silting up in the sewers, and in practice it has been found to realise the expectations formed of its working.

The Liernur System

In this system every house must be provided with two sets of drains—one for household waste waters and rain water, the other for the fæcal matters from *cabinets d'aisance* without water supply, for the water-closet sewage, and for bedroom slops containing urine. The first set of pipes joins the pipe drains in the street, which receive rain water and the waste liquids from factories, and the contents are finally discharged into the nearest watercourse (canals in Holland).

The *cabinets d'aisance*, or 'air-closets,' as they are termed, consist of cast-iron hoppers with siphon traps, but without water supply. They are connected with the branch sewer pipes in the street by means of 5-inch cast-iron soil pipes, trapped with a siphon bend below, and continued up above the roof by 2-inch ventilating pipes.

The branch sewer pipes are also 5-inch cast-iron pipes with gas-tight joints. These pipes are laid in lengths of long downward slopes of 1 in 250, and short upward slopes of 1 in 5, forming inverted siphons, where the sewage matters rest at varying heights, according to the volume of sewage. These inverted siphons are ultimately connected with a cylindrical iron reservoir placed below the surface of the street in the centre of a district of from fifteen to forty acres, the town being divided into these districts. These reservoirs are connected with the works outside the town, where air-vacuum pumps are at work, by two sets of pipes. The smaller set are the air-pipes opening into the top of the reservoir, and the larger set opening from the bottom of the resevoir serve for the transport of the sewage to the works.

A vacuum is produced within the street reservoir by connecting it with

the works; the valve on the street sewer pipes is then turned, and the sewage from the branch sewers is sucked into the reservoir. As soon as this is nearly full, air is admitted, and the sewage is then sucked into a reservoir at the works. The arrangement of the branch sewer pipes as inverted siphons causes approximately equal emptying of their contents into the street reservoir. In those branch pipes that are full the sewage will stand up to the top of the bend of the siphon, and will consequently be more easily drawn away than those which are less full, and in which the sewage has to pass up a greater length of the bend. As soon as the levels of sewage in the siphons of all the branch pipes are the same, they are all emptied equally until bubbles of air begin to pass, when no more sewage flows, leaving the pipes still trapped.

In Amsterdam, where the Liernur system is at work, the sewage contains but little diluting water, as the majority of the closets in the town are 'air-closets' without water supply. At the works outside the town the sewage is further concentrated by heat, and dried in revolving cylinders, when it issues as a powder—said to be worth 8 francs per 50 kilos. (about 6*l.* 10*s.* per ton).

The system appears to be well adapted for flat towns intersected by numerous canals, such as are to be found in Holland, where sewerage by gravitation presents great difficulties; and it certainly appears as if it could be ordinarily conducted without the production of offensive odours, either given off from the street reservoirs or from the 'air-closets' within the houses.

The Berlier System

This system has been adopted in one of the districts of Paris. In principle it is very similar to that of Liernur. The house drains are connected with iron pipes, in which a partial vacuum is maintained by means of an air pump, so that the sewage is conveyed from the houses by pneumatic pressure to the pumping station, which may be outside the town.

The distinguishing feature of the Berlier system is its automatic action, which is a great improvement on the Liernur plan, in which the pipes and receivers can only be emptied by the opening of valves by hand. In the Berlier system every house drain is provided with an air-tight receptacle, in which the sewage collects until nearly full, when by a floating-valve arrangement the aperture leading to the sewer pipes is automatically opened, and the sewage is sucked away.

The system seems to be well adapted for Paris, where the existing sewers being so entirely unsuited to the water-carriage system of excrement removal, excretal refuse must be retained in the vicinity of houses in cesspools, or in some form of midden pit or dry closet, unless it be removed in a system of small sewers not depending on gravitation as a motive force.

THE DISPOSAL OF SEWAGE

The Rivers Pollution Prevention Act of 1876 made it illegal to discharge crude sewage into a stream, this term including rivers, streams, canals, lakes, and watercourses other than those mainly used as sewers, and also the sea to such extent, and tidal waters to such point, as may after local inquiry, or on sanitary grounds, be determined by the Local Government Board. This Act has very generally been disregarded during the dozen years and more it has been supposed to have been in operation, owing to the magnitude of the interests involved in the continuation of the old conditions. By the

Local Government Act, 1888, the duty of preserving the purity of our streams and rivers has been in part transferred from the local sanitary authorities to the County Councils, and it is to be hoped that this transference of powers will be followed by a more adequate enforcement of the provisions of the Act.

It will be advisable at this point to consider briefly the effects produced by the discharge of crude or incompletely purified sewage into fresh running water.

The magnitude of the evils which result from this practice is to a considerable extent dependent upon the proportionate volumes of sewage and clean water thus mixed together. If the sewage is comparatively small in volume, and is at once largely diluted with clean river water, it becomes in course of time to a great extent purified. The chief agent in this purifying process is the atmospheric oxygen dissolved in the water, which has considerable oxidising effect upon the organic matters of the sewage. As this dissolved oxygen becomes used up, a fresh supply is absorbed from the air; but actively growing aquatic plants also give off oxygen and reoxygenate the water, thus enabling the process of purification by oxidation to continue. Besides the water-plants, minute animals (infusoria, entomostraca or water-fleas, anguillulidæ or water-worms) are found in countless numbers in the polluted reaches of rivers; and these feed on some of the organic impurities of the sewage, and thus contribute towards the purifying process. The coarser kinds of fish, too, the carp, roach, and chub, feed on some of the elements of the sewage, and aid the process of purification. The suspended matters of the sewage tend to deposit largely in streams with sluggish current, and thus may be productive of nuisance in the immediate neighbourhood of the sewer outfalls; whilst the water below, being relieved of their presence, is in a better position to benefit by the natural oxidation processes. The agitation of the water and its exposure to the air, brought about by its flowing over rapids or falling over weirs, exerts a marked beneficial influence on its quality—no doubt from the increased oxidation of organic matters.

That polluted river waters can undergo self-purification is now very generally recognised. The essential conditions are that the polluting liquids shall be rapidly diluted with a large volume of clean water, allowing the natural purifying agencies of oxidation and animal and vegetable aquatic life free play. The completeness with which this self-purification is accomplished, or, in other words, the question as to whether a river water once polluted with sewage can ever attain its original purity or be a proper source of water supply, is one which we are not called upon to discuss here. It is sufficient to state that under favourable conditions polluted river waters can regain that state of purity which, as evidenced by chemical and biological examination, they formerly possessed. But, practically, in this country rivers which are once polluted with sewage so continually receive fresh accessions of sewage from the towns situated lower down on their banks that the processes of self-purification are brought to a standstill, and the contamination of the water gradually but constantly increases from the source to the mouth of the river.

Under these circumstances the dilution of the sewage with clean water is insufficient. The dissolved oxygen in the water is used up in the processes of oxidation of organic matters; the fish, first of all, and subsequently the lower forms of animal and vegetable aquatic life, are destroyed by the absence of dissolved oxygen or by the presence of noxious organic matters in the water, and then the natural oxidation processes come to an end. Putrefactive processes are started by a great increase in the numbers of the bacterial organ-

isms, fermentative changes take place in the organic matters, and foul gases are evolved. The bed of the river becomes coated with a deposit of decaying sediment, particles of which, buoyed up by the gases, occasionally rise to the surface to sink again, and a nuisance of a most injurious character results.

The nuisance is most marked during a period of warm weather. In the cooler months of the year the oxidation processes may be in action to a considerable extent; but on a rise of temperature, especially if the volume of clean water becomes at the same time diminished by absence of rainfall, the growth of bacterial organisms becomes stimulated to such an extent that decomposition sets in and replaces the ordinary processes. This happens to the Thames below London in the neighbourhood of the sewage outfalls pretty nearly every summer, when the temperature is high and the land water small in amount. During the rest of the year the river is not so productive of nuisance, although there can be but little doubt that its purifying powers are at nearly all times being tested to the height of their capacity.

The discharge of crude town sewage, then, into rivers is a practice fraught with so many evils and dangers that it cannot be too strongly condemned in all cases where towns or villages are situated on the banks lower down, or derive their water supply from the polluted source.

The discharge of sewage into the tidal waters of rivers and into the sea must next engage our attention; and here, of course, there can be no question of contaminating potable waters, for now, at any rate, the provision of water for domestic purposes from the tidal portions of rivers is unknown.

In the case of the tidal waters of rivers the reports of the Royal Commission on Metropolitan Sewage Discharge throw considerable light on the part played by the currents and tides on the sewage discharged into them, and serve entirely to negative the idea previously entertained that sewage discharged into a tidal water is at once carried away to sea.

In the first place, it is pointed out that the only true sources of dilution of the sewage are the land water entering from above, and the sea water passing up from the mouth of the river. The displacement of the sewage towards the sea depends to a very great extent upon the volume of land water entering from above. When this is but slight in amount, owing to absence of rain, the sewage is displaced towards the sea with great slowness; in the case of the metropolitan sewage the displacement in dry weather is said to be only a quarter of a mile daily. The result is that the sewage discharged at high water on any particular day is carried down with the tide and then back again to within a very short distance of the outfall. At each high tide it receives a fresh accession of sewage, so that a considerable accumulation or concentration of sewage in the river takes place, forming what has been termed a 'sewage zone,' and this is entirely due to the tidal oscillations. It is evidently a mistake, then, to regard the river water into which sewage is discharged at Barking or Crossness as clean water; it is, in fact, water that by reason of the tidal oscillations has already become the recipient of an accumulation of successive previous sewage discharges.

There is still another drawback to be considered in connection with the discharge of sewage into a tidal river. Any sewage which is not discharged within a short period after high water will be carried up by the flowing tide above the outfall; and when neap tides are giving place to spring tides the whole volume of discharged sewage is carried up daily higher and higher above the sewer outfalls as the spring tides increase. In this way sewage may be carried up into the heart of London, or even above it.

It is necessary, then, to store up the sewage at the outfalls in a reservoir and to discharge it as quickly as possible at the top of the tide. But at high

water there is a larger proportion of sea water in the river than at any other time, and the various salts contained in the sea water cause a considerable precipitation of the organic matters in the sewage. The processes of purification by oxidation are lessened by the presence of these salts, and there is a greater tendency to the deposition of sewage mud than if the sewage was discharged into fresh water.

The silting up of the bed of the river and the formation of mud banks and shoals is a very serious matter in the case of navigable waterways. There can be little doubt that the solid matters of the sewage are largely deposited in the neighbourhood of the sewer outfalls, and are not to any great extent carried out to sea in a state of suspension in the water.

The nuisance that may result from the emanations of a sewage-polluted river is patent to all, but the question of injury to health from such emanations is one more difficult to decide. In the case of the metropolitan sewage the Commissioners agreed that indisposition and a low state of vitality amongst those who were actually upon the river or lived on its margin might be attributed to its offensive condition, but the smell was in no case perceptible a short distance away from the river; and in the case of towns or villages upon its banks it was found impossible to separate the influence of the river from other causes productive of high mortality, which were very generally present.

The discharge of crude sewage into the sea rests upon a somewhat different footing from its discharge into a tidal river. Here the volume of sea water is so enormous in comparison with the sewage that if it can only be ensured that the sewage at once mixes with a large volume of sea water, the dilution of the offensive organic matters is sufficiently complete to render them innocuous. Certain conditions, however, must be observed to arrive at so satisfactory a result.

The position of the outfall with regard to the town must be so chosen that the sewage will always be carried out to sea, independently of the tides, and the possibility of its return avoided. Should there be only one current, setting in at a particular tide, available for carrying the sewage away, then a reservoir must be provided for storing the sewage at such states of the tide as are unsuitable to its discharge. In the case of a current setting along the shore, rather than off it, the sewer outfall should, of course, be placed at that extremity of the town which will prevent the sewage being carried along the whole sea front. The prevailing winds must also be carefully studied, so that floating matters in the sewage may not be blown back towards the town. The mouth of the outfall sewer should be below the level of the water at all states of the tide, and should be provided with a tidal valve to prevent the ingress of sea water.

In certain towns where these conditions have not been fulfilled the sewage discharge has been productive of much nuisance. The sewage has been borne along the whole sea front of a town by the set of the currents, and foul matters have been deposited on the foreshore, to the great detriment of the health reputation of these towns as watering places.

It is generally recognised that sewage discharged into a river or sea is altogether wasted; but this opinion is not shared by Sir John Lawes, who believes that the sewage is to a certain extent utilised by the fish feeding upon that which the sewage produces. The sewage which is discharged into the Thames he considers to be at first more suitable for animal than for vegetable life, but the products of the animal life become food for vegetation, and this vegetation in its turn is the food for fish. The removal of the sewage from the river, or even the removal of the sedimentary portion by

means of lime, would, Sir John Lawes thinks, be followed by a most serious reduction in the present quantity of fish. And he further adds: 'Looking at the great cost which must be incurred before the sewage could be employed beneficially upon land, it is quite probable that as a source of national wealth its value is greater in its present state than it can be by any other process applied to it.'

Apart, however, from the fact that great injury has been done to the fishing interest in the Thames itself—for the fish which formerly abounded in the river as high as London have now been driven down below Gravesend by the sewage discharge—we have it, on the great authority of Prof. Huxley, that all the great sea fisheries are inexhaustible; that is to say, that nothing man can do can seriously affect the number of fish in the sea. Mr. C. E. Fryer, of the Government Fisheries Department, has also pointed out that the fishery of all others that has shown the most marvellous growth is the Scotch herring fishery, which has always been prosecuted far from the influence of sewage discharge, and is every year being carried on more and more successfully at a greater distance from the shore. He also states that the 600,000 tons of fish annually brought ashore in this country are collected from an area of about 150,000 square miles, with a maximum depth of about 350 feet; and he asks, How are the constituents of London sewage to be spread with anything like uniformity over this vast area? We consider, then, that Sir John Lawes has entirely failed to show that the sewage cast into the sea is not completely and utterly wasted.

THE PURIFICATION AND UTILISATION OF SEWAGE

Its Chemical Composition and Value

We have already seen that the discharge of crude sewage into streams, the estuaries of rivers, or into the sea, means the entire waste of such valuable manurial ingredients as the sewage may contain. Owing to the density of population in this country, and the large numbers of towns and villages on the banks of every stream and river, the discharge of crude sewage into these watercourses is almost invariably productive of nuisance to a greater or less extent, and of injury to the fishing and other interests, which are entirely dependent upon the purity of river water. In the case of all towns, therefore, which are unable to get rid of their sewage directly into the sea, the problem of purification of the sewage before discharge has to be attacked, and the question at once arises—*Is it worth while to attempt the utilisation of the manurial ingredients of the sewage?* and as a corollary—*Is it possible to practically combine utilisation with purification, and to make the process pay the whole or part of the expenses incurred in its adoption?* Our first concern, then, must be to consider what are the amounts and values of the manurial ingredients contained in ordinary town sewage, and how far is it possible to reason from such theoretical considerations on the value of sewage or sewage products to the practical farmer.

The Rivers Pollution Commissioners in their first report gave the average composition of sewage in water-closeted towns as represented in the table on page 855.

The quantity of nitrogen existing as nitrates and nitrites is inappreciable.

This composition represents an average of a large number of analyses, and being merely an average its approximation to the average strength of sewage in any town can only be determined by actual experiment and observation. The sewage of different towns will vary very greatly in character accord-

ing to the proportionate number of water-closets to dry closets or middens in the town, according to the amount of water supply per head of the popula-

In 100,000 *parts.*

Suspended Matters 44·69		Solid Matters in Solution 72·2				
Organic	Mineral	Organic Carbon	Organic Nitrogen	Ammonia	Total Combined Nitrogen	Chlorine
20·51	24·18	4·696	2·205	6·703	7·728	10·66

tion, according to the amount and composition of the waste waters discharged from manufactories into the sewers, and, most of all, according to whether brick sewers are in use, which receive storm waters and allow subsoil water to percolate through their walls, or a separate system of pipe sewers has been adopted for the exclusion of surface and subsoil water. With the system of pervious drain sewers the dilution of the sewage during and after rainfall is often so great that the mixed rain and sewage has very few of the characteristics of sewage. Under the pipe system, on the other hand, the average strength of the sewage tends to be maintained independently of rainfall throughout every day of the year.

Not only does the sewage of different towns vary so greatly in composition, but the sewage of the same town—more especially where the sewers are of pervious materials—varies in strength from day to day, and from hour to hour. The daily variations depend largely upon the occurrence or absence of rain, whilst the hourly variations are occasioned by the habits of the populations. Thus, the sewage is strongest during the hours of the forenoon, and its flow greatest, whilst at night the sewers may be discharging nothing but subsoil water.

From these considerations, then, it will become evident that to obtain an exact knowledge of the average strength of a day's sewage in any town, samples must be taken at least every hour, and these samples must be mixed in order to procure an average sample for analysis—not in equal proportions, but *in such proportions as are indicated by gauging the flow of sewage at the time each sample was taken* (as first pointed out by the British Association Sewage Committee). This precaution is necessary in order that an average sample may be procured; that is to say, a sample which would be identical in composition with that which would be obtained if the day's sewage flowed into a tank large enough to contain it all, and was well mixed before the sample was taken.

In the same way the average yearly composition of the sewage of any town can only be determined by the analysis indicated above, carried on through every day of the year, and, by combining these analyses according to the daily volumes of sewage they represent, in the same way as for the daily average. In practice, however, all that it is generally necessary to know is the average composition of the dry-weather flow of sewage.

Owing to the labour involved, calculations of the average composition of sewage as above have been little, if at all, made. The hourly variations in the strength of town sewage must more especially be borne in mind when it is necessary to determine the purity of a sewage effluent from a purifying process such as that of precipitation. For it is plain that if the samples of effluent and sewage are taken at the same time of day, the effluent does not represent, for it is not derived from the sewage arriving at the works at that precise period, but is derived from sewage arriving at the works several hours

before, which may have been night sewage, and therefore little but subsoil water.

The chief valuable ingredients of sewage are the different forms of combined nitrogen, the phosphates, and the salts of potassium. The Rivers Pollution Commissioners gave the money value of these constituents *dissolved* in 100 tons of average sewage of the composition given above as being about 15*s*., whilst the *suspended* matters contain only about 2*s*. worth of them; total value, therefore, 17*s*. This gives a value to the sewage of a fraction over 2*d*. per ton. It has already been shown that the annual excretal refuse of an individual of a mixed population may be taken as being equivalent to 10 lbs. of ammonia, worth 6*s*. 8*d*.; and this refuse, if diluted with water to form forty tons of sewage (corresponding to an average dilution of 24 gallons per head daily, which is the average dilution of the dry-weather sewage in London), will also give a value to the sewage of 2*d*. per ton. These values decrease with increasing dilution, until when this amounts to 122¾ gallons per head daily (or 200 tons per head per annum) the theoretical value of the sewage is only ⅖*d*. per ton. This is an amount of dilution not infrequent in London during periods of very wet weather. Sewage of the composition given by the Rivers Pollution Commissioners contains about 117 parts of total solid matters (in solution and in suspension) per 100,000. It therefore follows that 855 tons of this sewage contain one ton of solid matters, and the ammonia in one ton of these solids amounts to 179 lbs., worth 5*l*. 4*s*. 5*d*. at 7*d*. per lb., the remaining valuable ingredients being worth 2*l*. 0*s*. 11*d*., or the value of the whole 7*l*. 5*s*. 4*d*.

We have already alluded to the character of the sewage in the midden or non-water-closeted towns, and shown that in composition it does not differ in any very material respects from that of the water-closeted towns (see p. 854). The Rivers Pollution Commissioners gave the following as the average composition of midden town sewage:—

In 100,000 *parts.*

Suspended Matters 39·11		Solids in Solution 82·4					
Organic	Mineral	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrates	Total Combined Nitrogen	Chlorine
21·3	17·81	4·181	1·975	5·435	0	6·451	11·54

On comparing this analysis with that of the water-closet sewage, it will be seen that the suspended matters are somewhat less in amount, whilst the solids in solution are greater. The total combined nitrogen is also below that of the water-closet sewage, but the chlorine is in excess, more persons contributing to a given volume of sewage in midden towns than in water-closet towns, owing to the absence of the water used in flushing the closets of the latter.

Nearly all the processes for purifying and utilising sewage fall under two heads, viz. those in which an attempt is made to separate the polluting —which are also the manurial—ingredients of the sewage from the water, which is the vehicle for their conveyance, and those in which the sewage is conveyed directly to and disposed of on land. In the first class may be considered those processes of straining, subsidence, and precipitation which aim at removing the suspended matters, at any rate, from the sewage, to be subsequently manipulated into a more or less convenient form for application to land as solid manures, whilst the liquid in a clarified condition is allowed to discharge at once, or after filtration through specially constructed filter

beds into the nearest watercourse. This subsequent filtration has been adopted, as we shall see later on, in order that the effluent liquid may attain to some compulsory or otherwise satisfactory standard of purity.

Straining, Subsidence, and Precipitation

In some few towns at a former time attempts were made to strain the sewage by passing it through filters constructed of gravel, ashes, or charcoal. The sewage was deprived of its suspended matters, but the filters very rapidly became choked, and had to be renewed at very great cost at frequent intervals. Although the sewage is clarified when the filtering medium is new, it was found that when not renewed with sufficient frequency it became possible for the effluent water to pass away with even more valuable elements than the raw sewage itself possessed. The manure, too, produced by the retention of the solid matters in the filter was only usefully employed, owing to its admixture with ashes or charcoal, to mix with and lighten stiff soils. It was not in itself a fertiliser of any but the slightest value. Owing to the great cost incurred in the frequent reconstruction of the filters, and to the fact that the sewage so treated was only clarified, and in no degree deprived of its soluble polluting ingredients, these processes of straining or simple filtration have been everywhere now discontinued.

When sewage is allowed to settle in tanks, the suspended matters in course of time subside to the bottom, and a more or less clarified liquid can be decanted from the top of the tanks. In this way, then, it is possible to attain quite as good a result as with the filters previously described, and without the inconvenience and cost arising from the periodical renewal of the filtering medium. But the subsidence of the suspended matters in sewage is a slow process, necessitating the provision of large tanks for the sewage to settle in and the expenditure of large sums of money in their construction and in the acquisition of the requisite land.

It soon came to be recognised that the addition of certain chemical substances to the sewage, when mixed with it prior to its entering the settling tanks, causes a more rapid and copious precipitation of the suspended matters than can be effected by subsidence alone. By such means it was found feasible to reduce the tank accommodation, and at the same time to obtain a more satisfactory effluent.

The number of chemicals that have been used, or advocated, as precipitation agents is enormous. Many of them have proved worthless on practical trial, whilst others, like the various phosphate processes, though shown to be effectual as precipitating materials, depended on what is now known to be the wrong principle of introducing valuable substances into the sewage in the hope of recovering them in the deposited sludge to which they would give a certain fictitious value. Others, again, have been abandoned as being more expensive than certain cheaper substances, whilst not giving any better results. Even to enumerate all these various processes that have at one time or another been tried and then abandoned would be tedious in narration, and unproductive in result, as we are more particularly concerned here with those methods that have stood the test of experience and are acknowledged to be, so far as at present known, the best and readiest means of attaining the end desired.

The three chief substances on which at the present time, in a large majority of instances, is reliance alone placed are *lime*—as lime water or as milk of lime—*sulphate of alumina*, and *protosulphate of iron*.

Lime exerts a precipitating effect upon sewage by combining with free

carbonic acid in the water, and with the partially combined carbonic acid of the bicarbonate of calcium, forming an insoluble carbonate of calcium (chalk) which is deposited; and this precipitate carries down with it most of the suspended organic matters of the sewage. These substances sink to the bottom of the settling tank, and form the so-called 'sludge' of sewage. The clear supernatant liquid remains above, and is known as the 'effluent.'

Lime has been longer in use as a precipitation material than any other substance. Leicester, Tottenham, and Blackburn were among the first towns to adopt the lime treatment of sewage. Until recently it was generally used as cream or milk of lime (lime slaked and mixed with water) in the proportion of some fifteen grains of the lime to the gallon of sewage. Within the last few years lime water (lime dissolved in water) has been recommended as being equally efficacious with a proportionally less quantity to the gallon of sewage—viz. five grains instead of fifteen.

There can be no doubt that the lime process, when worked under the proper conditions of a sufficient quantity of the precipitant intimately mixed with the sewage, and of adequate tank accommodation for settling, can be made to effect a very complete deposition of the suspended matters of the sewage, and that thereby it is possible to remove the grosser sewage odour from the effluent. The treatment has, however, very little, if any, effect in precipitating the organic matters in solution, and the ammonia likewise remains unaffected, so that the effluent water carries with it nearly all the valuable manurial ingredients of the sewage, and the sludge left at the bottom of the tanks is comparatively worthless. If the lime is used in too great a quantity, the sludge and effluent are rendered distinctly alkaline, and the tendency to secondary fermentation and decomposition is much promoted. It seems also that the use of an excessive quantity of lime, while affording a rapid settlement of the sludge and a very clear effluent, dissolves a considerable quantity of the offensive matters previously in suspension, and thus renders the effluent stronger and fouler than it need be. This constitutes the great drawback to the use of lime alone in the treatment of sewage, as it is of the greatest importance that the effluent should be discharged in as fresh a condition as possible, and that the sludge should not putrefy whilst collected in pits prior to pressing or drying. There is, besides, a tendency when the sludge is alkaline for it to lose what little ammonia it may possess in the process of drying.

The precipitation effected by sulphate of alumina is due to its combination with lime or carbonate of calcium in the alkaline sewage to form sulphate of calcium, whilst the aluminium hydrate is precipitated in a flocculent state, entangling and carrying down much of the suspended organic matters, whilst some slight portion of the soluble organic matters is also thrown down. In some cases as much as 5 per cent. of these soluble matters may be deposited with the rest of the precipitate. In other respects the effect produced is very much the same as that resulting from the lime treatment; that is to say, the sewage is clarified, but still contains the greater portion of its polluting and nearly all its valuable manurial ingredients. The crude sulphate of alumina, however, which is generally used being somewhat acid, the sludge and effluent are neutral or even faintly acid. There is, therefore, less proneness to decomposition than is the case with the alkaline sewage sludge and effluent resulting from the lime process, and in this important respect sulphate of alumina is undoubtedly superior to lime. But there is the drawback that an acid effluent is harmful to vegetation, and therefore is less suitable as an irrigating liquid for land than an alkaline effluent; and, as we

shall presently see, inasmuch as the clarified sewage from a precipitation process can be very effectually purified on a very small area of land, this is a practice which is coming much into favour.

Lime and sulphate of alumina have been used together at various towns in this country—for instance, at Coventry and Hertford, to cite well-known examples—and, on the whole, these two agents are still generally recognised as practically the best precipitation agents when used in combination. The proportions in which they are employed should be such as to render the effluent as nearly neutral as possible. Where sewage of medium strength is to be treated, the quantity of lime used may be from five to seven grains per gallon, and of sulphate of alumina about five grains per gallon of sewage. It is, perhaps, hardly necessary to add that when used in combination the effect of these salts upon the sewage does not very materially differ from the effect that would be produced by an equal quantity of either. The matters in solution in the sewage are but little affected by any chemical precipitant, or combination of precipitants, yet discovered. The special advantage of the combination of lime and sulphate of alumina is the production of a neutral effluent and sludge.

Protosulphate of iron is used as a precipitating material by itself or as an adjunct to lime. It is essential that the sewage with which it is mixed should be alkaline; hence its frequent use in combination with lime. When so used, it forms a highly flocculent hydrated protoxide of iron, which, in falling to the bottom of the settling tank, carries the suspended matters of the sewage with it. According to Dr. Stevenson, this protoxide of iron acts as a carrier of oxygen, absorbing free oxygen and again giving it up to organic matters, just as the red blood pigment absorbs oxygen to again give it to the effete tissues. It therefore has a distinct purifying action on sewage by oxidation of organic matters when used in sufficient quantities. It also has considerable antiseptic properties, and tends to prevent the occurrence of putrefactive processes in the sludge and effluent. By the use of protosulphate of iron, however, the mud banks of the stream into which the effluent is discharged become blackened, owing to the formation of sulphide of iron. This is a disadvantage from a sentimental, but not from a sanitary, point of view.

Protosulphate of iron has been but little used alone as a precipitating agent. When used as an adjunct to the lime treatment it should be employed in about the proportion of from three to five grains per gallon of sewage. Mr. Dibdin, in the course of some experiments on the metropolitan sewage, found that on some occasions, especially on Saturdays, lime would not precipitate the sewage completely, a heavy scum rising to the surface, which was carried down on adding a little iron. This result he attributed to the unusually large amount of soap used on Saturdays for washing purposes.

The effect of the precipitants used on the sludge must be considered, as well as their ability to produce a well-clarified effluent. Sulphate of alumina is said to increase the bulk of the sludge, owing to the fact that alumina carries down with it a good deal of water, but the sludge is more easily pressed into cakes than when lime and iron are used. Precipitation by lime and iron, however, is more rapid than by any other process, and the iron tends to produce a dense sludge. It is very often the practice to add some lime to the wet sludge before pressing, even when lime is used to precipitate the sewage, in order to secure a coherent cake. What should be aimed at is to procure rapid precipitation of a sludge of but little bulk, which can be subsequently easily pressed into cakes.

It is probable that a combination of the three materials we have been considering is capable of producing the most highly clarified effluent, and, at the same time, a sludge which is most easily dealt with. The lime and sulphate of alumina should be used in about equal proportions, viz. about four or five grains to the gallon of sewage, whilst the iron may be less (about two or three grains to the gallon). It is certainly advisable that the whole quantity of chemicals used should not exceed fifteen grains to the gallon. The question of cost is, however, of much importance in considering this matter, for, inasmuch as the best chemical process cannot purify sewage, but only clarify it, it is almost always highly desirable that the effluent from a precipitation process should be further purified by filtration through specially prepared areas of land or other suitable filtering material. In such cases all that is required of the precipitation process is that it should precipitate the suspended matters of the sewage in a fairly effectual manner, and should do this at the least possible cost. The removal of the suspended matters is essential for the proper working of the filter beds, but the precipitation of organic matters in solution is not required, as these will be purified in the subsequent process of filtration. The cost of lime is about 1*l.*, of protosulphate of iron 2*l.*, and of sulphate of alumina 3*l.* per ton. It is evident, therefore, that the lime and iron process is somewhat less expensive than lime and sulphate of alumina, and that lime alone is likely to be the cheapest. The only disadvantage of the lime process is the alkaline sludge; but if this is pressed, no nuisance need arise, so that in those cases where the effluent is purified by filtration, treatment by lime alone is capable of doing satisfactorily all that is required, and at the least cost.

The lime process is especially adapted for the preliminary treatment of the sewage of those manufacturing towns where free acids and acid salts or metals in solution are discharged into the sewers with the waste waters of factories. If lime is used these matters are, to a great extent, precipitated, the acidity is neutralised, and the effluent sewage can be used to irrigate land growing crops. This is the process adopted at Birmingham, where the sewage contains immense quantities of 'pickling liquor;' milk of lime, in the proportion of fifteen grains to the gallon, is mixed with the sewage prior to its entering the settling tanks.

Amongst other materials used in combination with lime, iron, or sulphate of alumina may be mentioned clay, which is ground very fine, and subsequently mixed with the other precipitants, before being introduced into the sewage. It acts as a weighting material, causing a rapid deposition of the suspended matters, its effect being chiefly mechanical. It, however, considerably increases the weight of the sludge to be dealt with, and for this reason its use is in no great favour.

Animal charcoal and various forms of prepared carbon have also been tried for their deodorant properties, but it is doubtful if the benefit to be derived is equivalent to the enhanced cost introduced by such expensive reagents.

To ensure the most complete clarification of the sewage the following conditions must be fulfilled:—The sewage to be treated must be fresh and undecomposed, and the larger solid matters should be removed from it by means of a Latham's extractor before the admixture of the chemicals, or by straining the sewage through a metallic sieve with fine meshes. The chemicals must be added to the sewage before it arrives at the tanks, and at a spot a short distance from them, so that in its flow along the channel the sewage and chemicals become well mixed together. The admixture may also be accomplished by stirring up the liquid with rotatory beaters. There-

must be sufficient tank accommodation. The tanks are best arranged in series, so that the sewage may pass through two, three, or four tanks, according to circumstances. A double set should be provided, in order that the treatment of the sewage may continue at all times. The sludge must be removed frequently, but, of course, sufficient time must be given for it to settle in the tanks. If allowed to remain too long it will putrefy and give rise to nuisance. When emptied, the tanks must be thoroughly cleansed before being refilled. When the clarified effluent is discharged direct into a stream, it should be made to flow in a broad but thin stream down a rapid incline, and fall over a weir so as to secure its aëration; and with the same view the effluent channel should be at least a quarter of a mile in length, and kept scrupulously clean.

In most modern works the tanks are constructed and managed somewhat as follows: Each tank is from 4 to 6 feet in depth, and is divided nearly into two by a vertical brick partition parallel to its longest sides, round which partition the sewage flows. At the outlet of each tank should be built a weir, not more than half an inch below the surface of the sewage, over which the effluent flows into the next tank of the series, or into the effluent channel. Under ordinary circumstances the sewage need only pass—very slowly, but continuously—through a series of two tanks before the effluent is discharged. Intermittent precipitation, i.e. allowing the sewage a short period of complete rest in the tanks, has been tried, but does not seem to produce a better effluent than can be obtained by continuous working; and it requires, besides, greater care in management. After from one to ten days of continuous working, the flow of sewage through the series should be discontinued, and the sludge allowed to settle, the clear liquid above being drawn off through the open mouths of float valves into the effluent channel. The residuum of sludge is then allowed to settle, and finally pumped into a sludge well, from which it can be forced up in pipes to the filter presses.

This sludge contains from 90 to 95 per cent. of moisture. It was formerly the custom to allow it to dry by exposure to the air in pits, but this method was productive of much nuisance during the process of drying, so that it is now the usual practice to press part of the moisture out of the sludge in filter presses actuated by compressed air, by which a solid cake containing from 50 to 60 per cent. of moisture is produced.

Johnson's filter press, or that made by Manlove, Alliott, Fryer, and Co. (fig. 182), may be taken as a type of these machines. It consists of a number of grooved discs arranged in series, each disc having a central perforation, and separated from the disc on each side of it by a filtering cloth. The liquid sludge is forced between the discs by compressed air at a pressure of 100 to 120 lbs. per square inch; the liquid, being forced through the filter cloths and along the grooves on the discs, escapes, whilst the solid portions remain behind between the discs, to be subsequently removed as solid cakes. The expressed liquid is clear, but exceedingly rich in dissolved organic matters, and very offensive, and is therefore passed back into the outfall sewer to undergo treatment with the crude sewage, or, better, again separately treated.

The cakes taken from the filter press can be stored without causing any nuisance, until they can be sold or removed from the works. Or they can be further dried in steam-drying cylinders, and then ground into a powder containing about 20 per cent. of moisture. In this dried granular condition the manure is far more suitable for application to land than in the form of the moist and coherent cakes which issue from the filter presses.

The weight of sludge cake produced from a known quantity of sludge

taken from the tanks can be calculated from Professor Robinson's formula

$$X = \frac{10\,W}{100 - P},$$

where W = weight of sludge from the tanks, P = percentage of moistur remaining in the pressed sludge, and X = weight of sludge cake produced.

Mr. Dibdin gives the average composition of pressed sludge cake fron

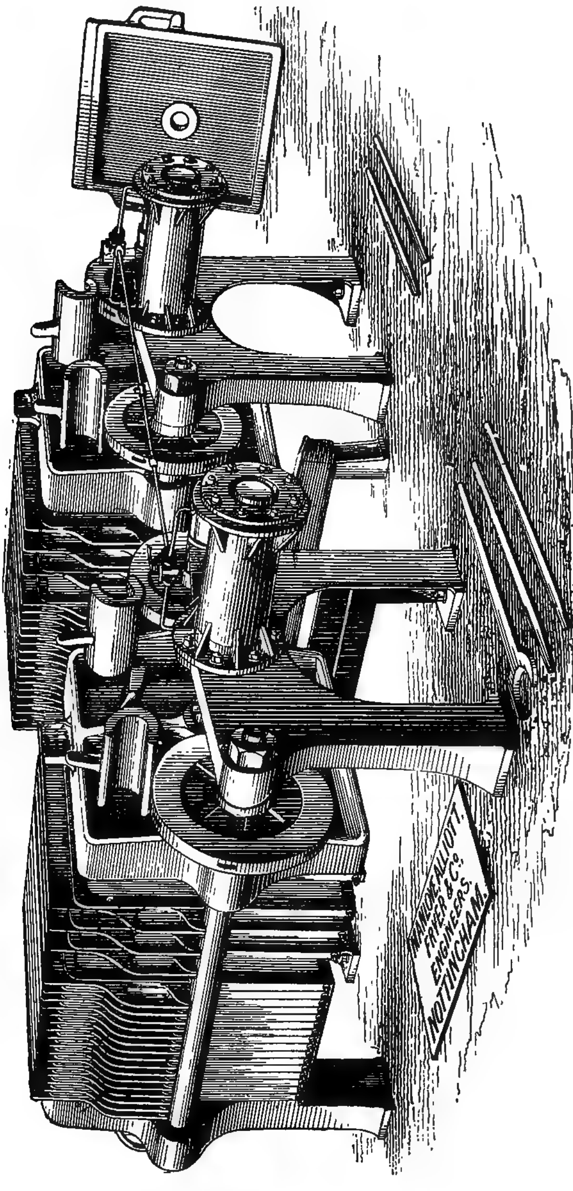


FIG. 182.—Sewage sludge filter press, actuated by compressed air.

the metropolitan sewage (lime and iron process) as: moisture, 58 per cent.; organic matter, 16·7 per cent.; mineral matter, 25·25 per cent.; ammonia, 1 per cent.; phosphate of lime, 1·44 per cent. On the calculation of its ammonia being worth 7*d.* per pound, the theoretical value of a ton of this sludge cake is 17*s.* The suspended matters from about

850 tons of sewage will be required to produce a ton of sludge cake containing 50 to 60 per cent. of moisture, so that on the supposition of the suspended matters in 100 tons of sewage being worth 2*s.* (see p. 856), we also see that the theoretical value of a ton of this sludge cake is 17*s.* Practically, however, this material is almost worthless, being so little suitable in its coherent form for a manure. It therefore usually has to be given away, or even the farmers may want a small premium for removing it.

As to the value of the more completely desiccated manures produced by a process of artificially drying the sewage sludge cakes, we may quote from a report of a very high authority, the late Dr. Voelcker, F.R.S., on the 'Fertilising and Commercial Value of Sewage and Night-soil Manures,' contained in the Report of the Committee of the Local Government Board on Modes of Treating Town Sewage (1876).

The theoretical or estimated money values of the manures were calculated from the quantities of the following constituents in each, namely, insoluble phosphate of calcium at 1*d.* per lb., soluble phosphate of calcium at 2*d.* per lb., potash at 2*d.* per lb., and nitrogen calculated as ammonia at 8*d.* per lb., these being the rates at which these fertilising constituents of manures may be bought in the form of concentrated artificial manures, such as guano, bone-dust, sulphate of ammonium, &c. The practical or market values were calculated as being from one-half to one-third of the theoretical values. The difference represents the greater expense in carriage and application to land of the more bulky and weaker manure, and the less efficacy and value of nitrogen in the form of nitrogenous organic matter, in which shape the nitrogen of sewage manures principally exists, than in the form of ready-made ammonia. For it must not be forgotten that sewage manures contain a large proportion of matters which occur in abundance in all or almost all soils, and which, therefore, having no commercial value, detract from the price by the cost of their carriage and application to the land.

As a further reason for the low practical value of these manures as compared with their theoretical values, Dr. Voelcker cites the case of farmyard manure. The theoretical value of a ton of good farmyard manure is, he says, about 15*s.*; but good dung can be bought in many places at 5*s.* per ton, or one-third its estimated money value; and practically the highest price which a farmer can afford to pay for good dung, if he has to cart it even a few miles, would not exceed 7*s.* 6*d.* per ton, one-half its estimated money value.

Value of One Ton of the treated Sewage Sludge	Theoretical or Estimated Money Value			Practical or Market Value			
	£	s.	d.	s.	d.	s	d.
Bolton sludge from the 'M and C' sewage process, dried to contain 15 per cent. of moisture	1	1	1	7	0 to	10	6
Solids drained from sewage before the liming process at Bradford, dried to contain 15 per cent. of moisture .	0	19	3	6	5 „	9	6
Sludge from Bradford sewage works, dried to contain 15 per cent. of moisture	1	0	0½	6	8 „	10	0
Sludge from 'A B C' process at Leeds, dried to contain 15 per cent. of moisture	0	16	8½	5	6 „	8	4

In the 'M and C' process, formerly in use at Bolton-le-Moors, lime, carbon (a waste product of the prussiate of potash manufacture), house-ashes, soda, and perchloride of iron were added to the sewage.

From Dr. Voelcker's report it appears that 'according to the most reliable statements the separation of the suspended matters of sewage by precipitation

and filtration, and the production of one ton of dried sewage deposit, apart from the costs of the precipitation agents which are used, entails an expense of about thirty shillings for each ton of portable dried sewage manure.' From the table of values above given it will be seen that, according to Dr. Voelcker's calculations, the cost of manufacture of every one of the manures there given considerably exceeds even its theoretical or estimated money value, to say nothing of its practical or market value. It is possible that at the present time, owing to improvements in machinery, it may be feasible to turn out the dried sewage manure at a somewhat less cost, but in any case it will be seen how hopeless it is to expect that the production of sewage manures will repay the cost of working a precipitation process, far less be the means of realising a profit.

The moist sludge from the precipitation tanks, which contains from 90 to 95 per cent. of moisture, is, of course, of even less value than the pressed sludge, and can only be regarded as a waste product which has to be got rid of without nuisance. This is the view taken at Ealing, where the moist sludge from the tanks, after losing some of its water by draining, is mixed with about two-thirds its volume of ashes and house refuse and is then burnt in a Destructor furnace. Another method of dealing with it, where land can be made available for the purpose, is that practised at Birmingham.

The sludge is raised from a well in the floor of the settling tank by revolving buckets, driven by steam, into temporary wooden carriers, along which it flows on to the land. Here it parts with some of its moisture to the air, and is then dug into the soil, which is subsequently planted and cropped for one year. At the expiration of the year the land is steam-ploughed, and kept cropped for two years, being occasionally used as a filter bed for the effluent from the tanks, and when the two years have elapsed it is again used for the reception of the sludge.

We may mention another method of dealing with the sludge, which presents some points of interest, namely, that invented by General Scott, and known as the 'sewage-cement' process, which was formerly carried on at Ealing and Birmingham. The sewage was precipitated in the tanks by lime and clay, and the sludge so produced when sufficiently dry was placed in a kiln and burnt by intense heat, the residue being then ground into cement. The great difficulty experienced was to dry the moist sludge with sufficient rapidity, filter presses not having been at that time introduced. By the use of modern filter presses the sludge precipitated by General Scott's process would be rendered dry enough to burn into cement, but the process does not appear to have been anywhere in operation in recent years.

We now come to the consideration of the treatment of the effluent. This we have seen to be merely a clarified sewage; that is to say, a sewage which is deprived of the whole or of the greater portion of its suspended matters, but still contains all the dissolved organic matters of the sewage. Three main points present themselves for consideration in discussing the advisability of discharging an effluent from precipitation works into a river. First, there is the question of nuisance likely to result; secondly, the injury to the river if used below the point of discharge as a source of supply for drinking water; and thirdly, the liability to injure or destroy the fish in the river.

With regard to the question of nuisance it may be stated broadly that no offence is likely to be caused if the effluent is sufficiently clarified and is discharged into a fairly rapid stream, of which the ordinary volume is at least ten times greater than that of the effluent. Under such circumstances the dilution of the foul water with clean is sufficiently great to enable those

processes of self-purification previously alluded to to have free play. There is, however, always the danger of the volume of fresh water in the river undergoing considerable diminution in times of drought; and at such times, especially in hot summer weather, it is always possible for the foul matters in the effluent to be insufficiently diluted, when they will undergo secondary fermentation; the river water becomes turbid, and in its bed a deposit of foul organic matters forms, which putrefies and gives rise to offensive gases. The silt thus formed tends to choke up the bed of the stream, and has to be removed at considerable expense by dredging operations. It therefore appears to be advisable that where streams are of very variable volume, according to the season of the year, the clarified effluent should be further purified before being permitted to enter them.

As regards the second point, it is now universally acknowledged to be unsafe, or at least inadvisable, to use a river as a source of water supply which has at any time received sewage or sewage effluents higher up in its course. Whether the sewage can be sufficiently purified by filtration through earth or other filtering materials to render the river into which it is ultimately discharged a safe source for drinking water is a point upon which no very reliable evidence is at present forthcoming.

On the subject of injury to fish Mr. Willis-Bund, Chairman of the Severn Fishery Board, contributed a very valuable paper to the Congress of the Sanitary Institute at Worcester, 1889. He divides the rivers of this country into four classes, viz. A. Rivers not containing fish. B. Rivers containing coarse fish—*Cyprinidæ*—only. C. Rivers containing coarse fish—*Cyprinidæ* and non-migratory *Salmonidæ*. D. Rivers containing migratory *Salmonidæ*. The coarse fish—the *Cyprinidæ*—are not injured to anything like the same extent by sewage in rivers as are the *Salmonidæ*. Of the coarse fish the hardiest are the carp and tench, and then, in a series of decreasing hardiness, roach, chub, dace, bleak, gudgeon, and minnow. Many of these fish, as is well known, habitually frequent the sewer outfalls into a river, and feed upon some of the elements of the sewage, and they will even live in a fairly clarified sewage effluent. But in the case of polluted rivers Mr. Willis-Bund points out that it is not merely a question of the fish being destroyed, but of how far the pollution affects their numbers and their size by interfering with their breeding and destroying their food, or by introducing into their water unwholesome food. There is great reason to believe that, although in many polluted rivers the coarser fish have not been to any great extent destroyed, yet they have had their numbers and the size of the individual fish seriously reduced.

The *Salmonidæ*, on the other hand, will only live in water that is practically pure, and they are besides of far greater value than the *Cyprinidæ*. And here, again, as regards the migratory species, the salmon, it is not so much a question of the actual poisoning of the fish by noxious sewage matters as of the hindrance offered by polluted reaches of a river to the passage of the salmon from the sea to their spawning beds in the river. If the pollution is sufficiently concentrated the salmon will not pass it, and being obliged to spawn in unsuitable places they gradually become extinct. Where sewage precipitation works are being projected on the banks of a salmon river, it will be necessary to secure a very pure effluent, otherwise the fish will be forced back, for the concentration of sewage matters is very considerable in the reaches of the river in the immediate neighbourhood of such works. Mr. Willis-Bund therefore suggests that for each of the classes of river A, B, C, and D a minimum standard of purity of sewage effluent should be agreed upon, and the Local Government Board should be induced

not to sanction any scheme for sewage works on such rivers the effluent from which did not come within the agreed standard.

The clarified effluent from a precipitation process can only be effectually purified by some method of filtration. Where land of good quality can be obtained adjoining the works, the process of intermittent downward filtration through specially prepared soil can be adopted with the best results; and this we shall consider subsequently. Where such land is not obtainable, filtration through magnetic oxide and carbide of iron can be made to give good results. A process of this nature is now in use at Acton and Hendon. The filtering material used is called 'polarite,' and contains about 50 per cent. of magnetic oxide and carbide of iron, combined with silica, lime, and alumina in an insoluble form. The filter beds consist of 18 inches to 2 feet of polarite, upon which rests a layer of sand about a foot in depth. The sewage is precipitated in tanks with a substance called 'ferrozone,' consisting largely of protosulphate of iron, and the effluent is then passed through the filter of polarite. The sand separates any suspended matter remaining in the effluent, and the organic matters in solution are to a very considerable extent oxidised when brought into contact with the polarite, as shown by the presence of nitrates and nitrites in the filtered water, which is moreover clear and colourless, and far freer from organic matters than the unfiltered effluent. The sand requires renewal from time to time, but the polarite can be left unchanged for very long periods, only requiring a daily rest for aëration of its pores. The slower the filtration—that is to say, the longer the effluent liquid remains in contact with the pores of the polarite—the greater is the purifying effect produced. It is said that such a filter bed can serve in place of a much larger area of land, and will produce an equally good result, one acre of filter bed being sufficient to purify from one to two million gallons of clarified sewage daily.

Spencer's magnetic carbide of iron has also been tried as a filtering material for sewage effluents, and gives very similar results. In fact, the two materials are probably very similar in nature and composition. We have here, then, a means by which without great expense and without acquiring any large area of land sewage can be, with care and attention, sufficiently purified to be rendered admissible into almost any stream, no matter what the original purity of its waters. It is important to note, however, that in these processes all the manurial ingredients of the sewage run to waste; for we can hardly regard the dried sludge as a valuable product, it being practically unsaleable, and the effluent water containing all the valuable matters is not made of any account, for none of these matters can be recovered from the filter beds, inasmuch as they are destroyed in the process of oxidation.

At this place it will be convenient to consider very shortly some of the more important patented processes for the treatment of sewage by precipitation.

The 'A B C' process (Sillar's patent) has been tried at Leamington, Leeds, Bolton, Crossness, and other towns, and is now in actual operation at Aylesbury and Kingston-on-Thames, being carried on by the Native Guano Company. A mixture of charcoal, clay, and blood (in very small quantity) is first mixed with the sewage, after which is added crude sulphate of alumina. A compound of manganese and some other ingredients were formerly added as well, but we believe these are not now introduced. A highly clarified effluent is produced by the process, which is, however, a costly one. The sludge is pressed in filter presses and subsequently dried in steam cylinders, and sold as a granular manure containing about 20 per cent. of moisture. The Company claim that this manure sells for 3*l.* 10*s.* per ton.

It is difficult to understand how mere dried sewage sludge can command so large a price, as it is certain that it cannot contain sufficient ammonia and phosphates to justify any such value. We have seen, too, what value the late Dr. Voelcker placed upon the dried 'A B C' sludge obtained from the sewage of Leeds (see p. 863). But the advocates of the process rely upon the practical results obtained by agriculturists from its use, rather than upon theoretical values based upon analytical data. Until these practical results obtained in the hands of farmers are published—and they are not at present—we are not in a position to discuss the question; but we are of opinion that some other explanation is called for than that offered by Mr. Sillar to the Royal Commission on Metropolitan Sewage Discharge, viz. 'that this sewage manure is the natural substance which was intended to manure the earth, and that the earth has a natural liking for it, independently of its actual ammonia or phosphate strength.'

At various times substances which act as deodorants or antiseptics have been used in combination with the chemical precipitants. These have mostly met with failure, partly on account of the expense involved in any attempt to deodorise large volumes of sewage with antiseptic compounds of high price, and partly owing to the fact that the antiseptic substances tended to escape with the effluent water, and to poison the fish of the river into which it was discharged.

The most successful of these processes appears to be the one invented by Hanson, which has been in operation at Tottenham and Leyton. At these places the sewage is treated with lime in the ordinary way and with black-ash waste (about four grains to the gallon of sewage). Crude black-ash waste is a refuse of alkali works, and is prepared and sold in London, in a granular condition suitable for mixing with sewage, at 3*l*. 10*s*. per ton. This substance contains about 30 per cent. of the sulphites and hyposulphites of calcium, which are powerful reducing or deoxidising agents, and impart to the waste considerable antiseptic and deodorising properties. They are not present in new black-ash waste, but are formed in the heaps of this material which have been long exposed to the air by the oxidation of sulphide of calcium. Some of the hyposulphite of calcium passes off in the effluent, as it is soluble in water. The adoption of the process at Tottenham and Leyton was followed by a great improvement in the condition of the river Lea, which had been very much polluted with sewage. Besides its deodorant properties, black-ash waste appears to prevent the formation of putrefactive bacterial organisms in the effluent, but it does not interfere with the growth of those microscopic organisms (infusoria, anguillulidæ, &c.) which, by feeding on organic matters, are capable of purifying foul waters, without the production of foul gases from putrefaction.

Mr. Dibdin, chemist to the late Metropolitan Board of Works, recommended the addition of manganate of sodium and sulphuric acid to chemically treated sewage. These substances, when used together, liberate oxygen, which tends to deodorise the sewage; but it is evident that the amount of such an oxidising agent which would be required must be very large to produce any appreciable result, and so the expense would be prohibitory.

The latest of these deodorising methods is that known as the Amines process, which has been tried experimentally at the Wimbledon Sewage Works and at Canning Town. The sewage is treated with milk of lime and with a small quantity of herring-brine, which contains a certain percentage of the compound ammonia, methylamine. This subtance when brought into contact with lime is said to give off a gas termed 'aminol,' which spreads rapidly through the sewage, and is a powerful antiseptic and deodorant. When

efficiently carried out, the process is said to effect a complete sterilisation of the effluent, all micro-organisms being destroyed, so that it (the effluent) undergoes no secondary fermentation even when kept at a high temperature in contact with the air. The sludge, too, is deodorised, or at least gives off only a briny smell, as well as the effluent, and it can be dried in pits exposed to the air, or on the floor of a drying kiln, without giving rise to any nuisance. Such being the case, the process of pressing in filter presses is rendered unnecessary, and a considerable source of outlay is thereby avoided. It will not serve any useful purpose to discuss the process in its present experimental stage, but it may be observed that the herring-brine is at present a cheap commodity; and it is evident that the use of deodorants and antiseptics as auxiliaries to precipitation processes must be advantageous if they retard decomposition without interfering with oxidation by natural agencies, and without injury to fish, and if at the same time they involve but little extra cost.

We have recently had an opportunity of seeing the Amines process at work at the Wimbledon Sewage Works and Farm. As recommended by the inventor of the process, the quantity of cream of lime used is very large, viz. about seventy grains to the gallon. The lime is mixed with the herring-brine before being introduced into the sewage. With this large quantity of lime the precipitation is very rapid, and after the clarified effluent is run off from the tanks, the sludge settled at the bottom may again be used as the precipitation agent, no chemicals being then added to the sewage. As the sewage flows into the tanks it stirs up the sludge, which becomes intimately mixed with it. The sludge may in this manner be used several times in succession before it is needful to add fresh chemicals to the sewage. The sludge, owing to the large quantity of lime it contains, is readily pressed into cakes in the filter presses, and these cakes are sold at Wimbledon at the price of 1*s.* per load (ton). The moist sludge may be dried in pits, without offence, and we inspected some which had been exposed to the air for some months in a pit, without, as we were informed, having at any time caused any offence in the process of drying.

A process of precipitating sewage by electrolysis has been tried at Crossness on the metropolitan sewage, and also at Bradford, in Yorkshire, in both cases merely as an experiment. The system is the invention of Mr. William Webster. The process, as experimentally tried at Bradford, is described by Dr. James MacLintock, Medical Officer of Health of the borough, in a paper read before the Public Medicine Section of the British Medical Association Congress at Birmingham, 1890 ('British Medical Journal,' Aug. 30, 1890). There is a very large proportion of manufacturing refuse in the sewage of Bradford, viz. dyes, acids, alkalies, grease, and other organic matters (wool washings) from the mills, the greater majority of which are engaged in the woollen industry. The large proportion of mill waste waters in the sewage renders it very difficult to obtain a satisfactory effluent with the lime process of precipitation, which is the one by which the bulk of the sewage at Bradford is at the present time treated.

The description of the electrical process is thus given by Dr. MacLintock:—

'The plant necessary for the electrical treatment is as follows:—(1) An electrolytic shoot or channel; (2) an electric generator; (3) motive power for generator; (4) necessary conductors for conveying the current to the shoot from the generator; instruments for measuring the current used and the potential at which it is supplied. The electrolytic shoot, constructed of brickwork, is 25 feet in length, 24$\frac{3}{8}$ inches wide, and 4 feet in depth. It is

divided into eighteen cells, each of which contains twenty iron plates, measuring 3 feet × 1 ft. 2 in. × $\frac{1}{2}$ in., and weighing on an average 70 lbs. each.

'These plates are placed vertically in the shoot, and present their edges to the direction of flow of the sewage. The cells are divided one from the other by partitions so arranged that the sewage in traversing the shoot passes alternately under and over them. Every alternate plate is connected respectively with the positive and negative poles of the generator. All the plates in each cell are connected up in parallel, and the cells are connected in series one with the other. The generator is a dynamo by Mather and Platt, of Manchester, capable of developing 100 volts and 180 ampères, but for this plant the full output of the machine is not required. The motive power is supplied from shafting in connection with a steam engine belonging to the Corporation. The raw sewage first enters the shoot, and passes into a settling tank, and then enters another shoot similar to the one described, except that it possesses eight cells instead of eighteen, and from there flows rapidly into three small tanks, and thence along a channel into the stream. During the process a greasy scum collects on the surface of the tanks and on the iron plates in the shoot. This is collected into a small tank partitioned off for the purpose.

'It is at once seen that the sewage is undergoing a change during its passage along the electrolytic shoot. Gas is disengaged, the fluid is changing colour to a slight degree, assuming a greenish hue; and, most important of all, a flocculent precipitate is being rapidly formed. In the first settling tank the greater part of this precipitate settles as sludge. The rest of the sewage flows into the second shoot, is there subjected to further electrical treatment, and is finally allowed to flow through the different tanks, where a further deposit takes place. The effluent flows into a channel where it is still further aërated, and then, as before stated, into the Bradford Beck, which is a tributary of the river Aire.'

The active precipitating agent formed by the electric current appears to be hydrated ferrous oxide, in a nascent condition, which is continuously being formed, and is used as fast as it is made. The arrangement of the plates and cells insures the most intimate and thorough mixing of the precipitating agent with the sewage. The continuous formation of the iron oxide, its nascent condition, and the thorough mixing of it with the sewage, are the special features of the process, which render it superior (according to the results hitherto obtained) to the ordinary treatment of sewage with salts of iron. The electrical treatment also possesses another advantage over lime or alumina processes, viz. that it adds very little to the sewage, and therefore limits the quantity of sludge to the lowest amount consistent with the removal of the suspended solids from the sewage.

The composition of the Bradford sewage before the electrical treatment, and of the effluent after it, are stated by Dr. MacLintock to be—

—	Sewage before Electrical Treatment	Effluent after Electrical Treatment
Total solids	127 grs. per gal.	66 grs. per gal.
After ignition	69 " "	47 " "
Loss on ignition	58 " "	19 " "
Chlorine	10 " "	9 " "
Free ammonia	32 parts per million	21 parts per million
Albuminoid ammonia . . .	15 " "	5 " "

From the fact that the loss of solids on ignition is reduced from fifty-eight to nineteen grains per gallon, it appears that nearly 70 per cent. of the

putrescible portion of the sewage is removed by the treatment. The reduction of albuminoid ammonia is also very considerable (66 per cent.), but the free ammonia is reduced to a less extent. No living organisms could be detected in the effluent, although the sewage was crowded with bacteria, infusoria, and other low forms of organic life.

The effluent is clear, with a slight yellowish-green tinge, and is little liable to undergo secondary putrefaction.

We may conclude, then, that the experimental trials already conducted show that the process is capable of purifying sewage, and even sewage of bad quality, in a higher degree than can be attained by the ordinary methods of precipitation with lime, iron, or alumina; but, on the other hand, the cost of the process will probably be found to be far in excess of that required for the latter methods. A large initial outlay is required for dynamos, steam motive power, electrolytic shoots, iron plates, and depositing tanks. The expense of working, too, must be high, owing to the consumption of power, whilst, from the quantity of iron present in the sludge and effluent, it is evident that a considerable amount of iron must be daily consumed and the plates will require frequent renewal.

To sum up, then, the conclusions at which we may arrive with regard to precipitation processes. They to a certain extent purify the sewage by clarifying it—that is to say, by causing a deposition of the suspended matters in the settling tanks—but they all leave a very large amount of putrescible matter in the effluent water—namely, all, or nearly all, the organic matters which are in solution in the sewage, and fail to remove any of the ammonia contained in the sewage, which invariably escapes in the effluent water. It is for this reason that the manures produced from the precipitated sludge are of so inferior a character, for the suspended matters that are precipitated from sewage constitute less than one-sixth of the value of its total fertilising ingredients. Precipitation processes, then, completely fail to utilise sewage to any advantage, and they only effect a partial purification. On the other hand, when employed merely as a preliminary to land treatment, as is now so largely the practice, they are capable of rendering services of great value.

Land Filtration

The first experiments on the filtration of sewage through the soil were made by the Rivers Pollution Commissioners about twenty years ago. It was then shown that sewage was capable of being very efficiently purified in its passage through a few feet of porous soil, but that to secure the best results the filtration must be from above downwards, and must be intermittent, in order that the pores of the soil may be aërated during the periods of rest. The process of upward filtration was tried, but was found to be inefficient in the purification of sewage from soluble offensive matters.

The purification of sewage by soil is, to a certain extent, due to the soil acting as a mechanical filter, separating and retaining the suspended matters in the sewage. But the principal agent is the oxidising power of the soil, by which ammonia and organic matters in the sewage are converted into nitrates, nitrites, and carbonates. This oxidising power is partly dependent upon the porosity of the soil, by which the particles of sewage are brought into contact with oxygen from the air retained in its pores, but chiefly upon the presence of nitrifying organisms belonging to the family of bacteria. These organisms are found in sewage itself, and are abundantly present in most soils, but chiefly in those rich surface soils of mould or loam which contain an abundance of organic matters. The experiments and researches of

Schloesing, Müntz, and Warington have shown that these nitrifying organisms (one of which has been isolated by Percy Frankland) feed upon the ammonia and organic matters of sewage, causing their oxidation, and that this nitrification is confined to the same range of temperature which limits other kinds of fermentation—that is to say, that the production of nitrates proceeds very slowly near the freezing-point, but increases in rapidity as the temperature rises, reaching its maximum of energy at about 99° F. Other essentials for the proper performance of nitrification are, that the soil be well supplied with air—hence the advantages of porosity in the soil and of intermittent application of the sewage—and also that some base, such as lime, soda, or potash, be present in the soil, with which the nitric acid as formed may combine. Without the presence of this salifiable base it has been found that nitrification will speedily come to a standstill.

In the choice of a soil, then, for the reception and purification of sewage the following conditions should, if possible, be fulfilled:—The soil should be of a rich loamy character, and therefore well supplied with the nitrifying organisms. It should be porous and composed of small fragments, both to allow of free aëration and oxidation and also so that it may present an immense surface, covered with the organisms, to the sewage while percolating through it. Pure sandy soils are not efficient purifiers until their particles have become coated with the nitrifying organisms present in the sewage, and then they act well. All retentive soils containing an excess of clay must be well broken up and mixed with town ashes or with ballast (burnt clay); and in such cases it is advisable to introduce as well a layer of alluvial or other rich soil.

The surface of the land must then be carefully levelled, to admit of the sewage flowing evenly over every part of it, and it should be under-drained with porous agricultural tile drains laid at a distance of 10 to 30 feet apart, according to the porosity of the soil, and at a depth of 4 or 5 feet from the surface. To lay these under-drains at a greater depth from the surface is now thought to be unnecessary, as the nitrifying organisms are not usually found at a greater distance from the surface than 4 feet, and are almost invariably present in greatest numbers in the first 18 inches of soil. The filtration area should then be laid out in plots, each plot to receive sewage for six hours only every day, so that it may have eighteen hours out of the twenty-four for necessary rest and aëration.

Where the sewage of a large number of people has to be applied to a small area of land, it is generally advisable to precipitate the suspended matters of the sewage by chemicals as a preliminary process, and to irrigate the land with the clarified sewage effluent only. As a general rule, which, however, must not be applied too strictly, it may be stated that where the sewage of more than 1,000 people must be applied to each acre of land, the sewage should undergo a preliminary precipitation; but if the proportion is less than 1,000 to an acre and the land is of suitable quality, the sewage should be allowed to flow on to it as it comes, or after a mere simple straining to remove the larger solid bodies. If the raw sewage is applied in too large volumes to a small area of land, the surface of the soil tends to become rapidly clogged with a thin layer of suspended matters and slime, and a coating is formed which prevents the percolation of the sewage and the penetration of air into the interstices of the soil. The slimy matters in sewage are derived from the grease of kitchen waste waters, the fats of soap, the mucus from the urinary and intestinal mucous membranes, and from macerated paper. The land has, therefore, to be constantly raked over, and the surface layers dug up and incorporated with those beneath with much labour and expense; if

this is not done the sewage stagnates and forms ponds on the surface and gives rise to nuisance as soon as decomposition commences.

This difficulty is entirely avoided by irrigation with clarified sewage only. There are other advantages besides this in adopting precipitation as a preliminary. Most of the bacterial organisms and their spores, the active agents in putrefaction, are carried down in the precipitate, and therefore removed from the effluent, which is consequently less prone to putrefy and readier to undergo nitrification in the soil, for putrefaction and nitrification are antagonistic processes, just as we have seen putrefaction and oxidation are. It would seem that, as a preliminary to land treatment, lime is the best precipitating material that can be used, as it introduces into the sewage effluent the requisite base for combination with the nitric and nitrous acids formed by nitrification. Lime is also the best material to neutralise the acids and acid salts contained in sewage which has received the waste waters of manufactories and chemical works; this kind of refuse proving a great hindrance to the purification of sewage by soil. The presence of antiseptics in the sewage also prevents nitrification, so that such deodorising agents as carbolic acid and perchloride of iron, which have been used as adjuncts to the lime process, must not be employed where the clarified sewage is to be applied to land. Whether black-ash waste or herring-brine are sufficiently strong antiseptics to prevent nitrification in the soil has not yet been determined; as regards black-ash waste, we should be inclined to think that, as it does not prevent oxidation processes and the growth of infusorial life in the effluent, it would not either have any prejudicial effect upon the nitrifying process in the soil.

It is probable that by intermittent downward filtration through well-drained beds of porous soil of suitable nature, the clarified sewage of as many as 5,000 people (100,000 to 150,000 gallons daily) may be applied to each acre of land without overdosing the soil with sewage or placing too great a strain upon its purifying powers. But as a set-off against the small area of land required to cleanse the sewage must be taken into account the cost of precipitating the sewage and subsequently dealing with the sludge. And it is even now doubtful if it is not better policy for a local authority to acquire a larger extent of land, and to allow the suspended matters to reach the soil by gravitation in the liquid sewage, rather than to incur the cost of separating them by precipitation, and then pumping the liquid sludge on to the land. Mr. Bailey Denton is even of opinion that, if properly distributed on carefully prepared surfaces, sludge on land generally does good rather than harm, and that it is only objectionable when mixed with trade refuse. He advises filtration beds to be laid out in ridges and furrows, the sewage being allowed to flow down the furrows, whilst vegetables (cabbages, roots, &c.) are grown on the ridges. The sewage obtains access to the roots of the vegetables, which assimilate from it ammonia and organic matters, and thus aid the purification. The leaves and stalks being above the sewage are not contaminated by floating matters, and therefore no exception can be taken to their use as articles of diet. The suspended and slimy matters of the crude sewage are deposited in the furrows. Before they have had time to form an impenetrable coating, the sewage must be turned off the plot, and the deposit allowed to dry and shrink, when it is easily broken up and incorporated with the soil.

When intermittent downward filtration is properly conducted on suitable land, the effluent water issuing from the under-drains is found to be very effectually purified. It will be almost entirely deprived of organic matters and ammonia, and the oxidation to which these have been subjected will be evidenced by the presence of a considerable quantity of nitrates in the

effluent. In fact, a very large proportion of the nitrogen of the sewage passes away in the effluent water in the innocuous form of nitrates and nitrites. The chlorine, however, will be found in very much the same proportion in the effluent as in the sewage. The purification is usually most complete during the warmer months of the year, when the nitrifying organisms are at a temperature suitable to the display of their most active properties, and when vegetable growth is at a maximum. In winter the purification may be less complete, but not necessarily so, as the oxidising and nitrifying power of a soil may be in excess of the work provided for it, so that even with a low temperature the usual amount of purification may be attained.

By intermittent downward filtration through small areas of land we see, then, that sewage may be very effectually purified, so that the effluent attains a high standard of cleanliness and is admissible into streams of great natural purity. But by this process all the manurial ingredients of the sewage are wasted, except in those cases where the sale of vegetables grown on ridges covers part of the cost of distribution; and even in these cases, as nearly all the nitrogen of the sewage is found in the effluent water, but little can be abstracted for the growth of produce or for the enrichment of the land The area of land, too, being so very limited, the amount of vegetable produce, and the income derived from its sale, must necessarily be very small. In fact, in the words of the Report of the Commission on Metropolitan Sewage Discharge, 'filtration is the concentration of sewage at short intervals on an area of specially chosen porous ground as small as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance.'

The cost of preparing land as an intermittent filter bed is much greater than that required for broad irrigation on the usual sewage farm plan; but then the efficiency of each acre in doing the work of purifying sewage is far greater by the former method than by the latter. Mr. B. Denton estimates the average cost of preparing land for a filtration area at about 70*l.* per acre.

As regards liability to nuisance, this is little likely to arise if the land is properly managed. Where crude sewage is applied to the soil, offence may be caused, as previously stated, by ponding of stagnant sewage owing to the clogging of the surface soil with slimy matters. Where the suspended matters are first precipitated, the storage of sludge on the premises or its application to land in a liquid state may give rise to nuisance; but it may truly be said, with regard to all methods of dealing with such foul waste matters as sewage, that unless ordinary care and attention are bestowed by those in charge the very best method is liable to fail and be productive of nuisance, and therefore that objections raised on this score apply less to the principle of the method pursued than to the manner in which it is carried out.

Intermittent downward filtration, preceded by a precipitation process for the removal of the suspended matters, was the method recommended by the Commissioners as offering the best solution of the metropolitan sewage discharge difficulty. The enormous quantity of precipitated sludge is the chief drawback to such a process, but the Commissioners thought it might be got rid of without offence by burning it, carrying it out to sea, digging it into land, or using it for raising low-lying lands at the mouth of the Thames.

IRRIGATION

Surface or broad irrigation was defined by the Royal Commission on Metropolitan Sewage Discharge to mean 'the distribution of sewage over a

large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied.'

We have already seen that large volumes of sewage can be very efficiently purified by filtration through small areas of suitable land carefully levelled and under-drained; but that although the purification is satisfactory, the utilisation of the manurial ingredients of the sewage is but little effected, as the area of land sewaged is too small to raise crops in any quantity, with the result that the nitrogen of the sewage to a large extent escapes in the effluent water in the form of nitrates. If, however, the same volume of sewage be applied to a much larger area of land, it is possible to utilise the sewage by the production of large crops of grass and vegetables, whilst its purification goes on as before.

It is evident, therefore, that a sewage farm should be an enlarged filtration area. The same forces are concerned in the purification of the sewage as were mentioned under land filtration; so that on every sewage farm the sewage should be applied intermittently to each field or plot of land; it should then sink into the soil, so that it may be filtered and oxidised, and finally pass away by means of under-drains into the watercourse which effects the natural drainage of the locality. Any system of irrigation by which the sewage is applied too continuously to the land, or by which it subsequently passes over the surface of the land and not through it, is likely to prove a failure by giving rise to nuisance from a water-logged condition of the soil and from insufficient purification of the effluent.

We can now consider the conditions under which sewage farming should be conducted, in order to attain a successful result both in the purification of the sewage and in its utilisation as a manure.

As regards the position of the farm with relation to the town, the sewage of which is to be applied to it, it is most important that the land should lie at such a level that the sewage may flow to it by gravitation. In many instances, however, the choice of land in the vicinity of a town is limited, and recourse has to be had to pumping. The pumping of large volumes of sewage on to a sewage farm is a costly process, and greatly reduces, or even annihilates, any profits that would otherwise arise from the sale of sewage-grown produce; there is, besides, the very great sanitary disadvantage that the capacity of the pumps may be exceeded at times when the volume of sewage is very large from admission of storm waters into the sewers, and if such is the case the sewage is backed up in the outfall and tributary sewers, leading to flooding of cellars in low-lying districts and deposit of putrid sediment.

To make sewage farming a profitable undertaking it is, of course, necessary that the land should be acquired at a reasonable price, little, if any, in excess of that paid for ordinary agricultural ground in the neighbourhood. In very few instances, however, has this been done. Local authorities have experienced the greatest difficulty in acquiring land for sewage irrigation, and in many cases have given enormous prices for agricultural land required for sewage farms, with the result that this capital expenditure, added to enormous Parliamentary and legal costs, has saddled the local rates with burdens, which for very many years cannot possibly be diminished to any appreciable extent by the sale of sewage-grown produce. Where land is rented for sewage irrigation, according to Mr. Bailey Denton, 2*l.* 10*s.* per acre is a price which should not be exceeded.

The nature of the soil of a proposed farm is a very important factor. Probably the best kind of soil is a porous and friable loam on a subsoil of

gravel. Such a soil forms a very efficient filter for the sewage which readily percolates into it, and it involves the least expenditure in under-drainage. Other porous soils containing considerable admixtures of sand and gravel are also capable of purifying and utilising sewage when properly managed; but dense clayey soils should, if possible, be avoided, as unless considerable expense is incurred in breaking them up and mixing them with town ashes, and in under-drainage, they prevent the percolation of sewage, which tends to run over the surface and to gain access to the streams in a very insufficiently purified condition, especially in winter, when vegetation is least active.

The extent of land to be acquired must be dependent upon a variety of circumstances, such as the cost per acre, the nature of the soil, the variation in the volumes of sewage between dry and wet weather flow, and the demands of the local markets for the grass and vegetables produced from it. Perhaps the average may be taken as one acre to every 100 persons of the population; but it must be clearly understood that no hard-and-fast rule can be laid down.

The amount of under-drainage required will depend partly on the nature of the soil and partly upon the extent of land upon which sewage can be applied in relation to the whole volume of sewage reaching the farm. Least under-drainage will be required for the lighter kinds of soil resting upon a porous subsoil, and where the area of land is large in proportion to the volume of sewage. For soils of medium consistence, or where the area of land to which sewage is applicable is relatively small, under-drainage must be thoroughly carried out—pipes of porous earthenware 2 inches in diameter being laid at a depth of from 4 to 6 feet from the surface of the soil, and in parallel lines from 20 to 100 feet apart, according to circumstances. These subsidiary drains should eventually be connected at suitable points with arterial drains of larger size which join the main effluent drain or channel that discharges into the stream at the lowest part of the farm.

The outfall sewer should conduct the sewage to the highest point of the farm, at which spot, before the sewage is allowed to flow over the land, it is generally advisable to screen it through a grid to remove the larger solid matters. From this point the land should fall away gently, so that the sewage may reach every part of the farm by gravitation. Certain portions of the land may, however, require levelling, to ensure the regular and even irrigation which is desirable. The main carriers for the distribution of the sewage should be constructed of masonry or concrete, in the form of open channels, which are easily flushed and cleansed; or stoneware channel pipes may be used. The subsidiary carriers need be nothing more than grips dug in the land, which can be filled in as soon as they become to any extent clogged with suspended slimy matters, and fresh ones dug in their place.

For applying the sewage from the main carriers to the surface of the land, the best plan, as a general rule, to adopt is that known as the *ridge and furrow system*. The surface of the ground is laid out in broad ridges —30 to 70 or more feet across—running parallel to each other, but at right angles to the main carrier, from which they fall away to a slight extent. Between every two ridges is a longitudinal furrow formed by the slope of the ridges towards each other. The furrow is some few inches (eight or ten) below the level of the centres of the ridges on each side of it. The sewage is applied as follows: A workman stops the flow of sewage in a main carrier by lowering a sluice, or placing a 'stop' of wood athwart the carrier, opposite the centre of a ridge. The sewage then overflows from the main carrier and passes down a grip in the centre of the ridge, from which it can be made to flow over the sides of the ridge towards the furrow by

throwing some earth into the central grip or by blocking the passage with a board. After a certain interval the sewage is allowed to flow a little further down the central grip, and then again made to overflow as before, until the whole area of land has received its allotted portion of sewage.

The *catchwater system* has been adopted at farms, such as that at Warwick, where the ground has a very considerable slope from the point of delivery of the sewage. The main carriers are carried across the direction of the slope along contour lines, so as to be more or less parallel to each other one above the other, and the sewage, as it overflows from the highest carrier, passes over the land below, such of it as is not absorbed reaching the carrier next below and again overflowing, and so on to the lowest carrier. The disadvantage of this system is that the higher portion of the land receives too much sewage and the lower gets little else than water.

Yet another plan is that known as the *pane and gutter system*, which is in use at the Croydon Sewage Farm, where there is a general very slight fall of the land. It is very similar to the catchwater system, the sewage passing from the main carriers laid across the fields, and spreading over the surface of the beds from above downwards. At the Croydon Farm the soil is rather retentive, so that there is a tendency for the sewage to have a surface flow only, without any large amount of percolation, and to be carried from one field to another until it passes away into the brook, with only such an amount of purification as is brought about by its exposure to the air and by the action of vegetation. It may be stated, however, that the sewage is very fairly purified at the Croydon Farm, at any rate in summer, by surface flow, and the effluent flows into the stream in a clear and colourless condition. The area of land available for irrigation is 500 acres, and as the population contributing the sewage is 100,000, the sewage is not applied in a larger proportion than about 200 persons for each acre. The sewage, too, is freed from its coarser solid bodies by means of a Latham's extractor before being used for irrigation, and this helps to prevent the deposit of foul sediment on the carriers and on the surface of the land.

One of the greatest difficulties connected with sewage farming is the necessity of dealing with the enormous volumes of dilute sewage brought to the farm by the drain-sewers of the combined system during and after periods of heavy rainfall. At such times it is often inadvisable to apply the sewage to land on which crops are being grown, which may already be sodden with moisture, and the area of fallow land may be insufficient to deal with the large quantities of dilute sewage that would have to be applied to it. An obvious method of getting over the difficulty is to relieve the sewers by means of a storm overflow direct into the river. In doing this it may be contended that the sewage is so excessively dilute that no harm is likely to arise from its being allowed to enter the river; yet, on the other hand, it must not be forgotten that the same amount of sewage would still enter the river, although with a larger body of water, that the manurial ingredients of the sewage so discharged will be wasted, and that in towns where accumulation takes place in the sewers on account of their faulty construction or of want of regular flushing, the sewage so escaping is actually very much stronger than it is in ordinary times; and besides there is always the danger of the poisons of enteric fever and other diseases being discharged into water which may be used by towns lower down for domestic purposes.

Another and less objectionable method is that recommended by Mr. Bailey Denton of connecting the storm overflow with osier beds laid out in ridges and furrows, the osiers growing on the ridges. On reaching these beds the flow of sewage is checked, and this causes the deposit of the floating

solid matters in the furrows, whilst the flood water rises and overflows the ridges and the osiers growing on them. These beds need not be under-drained, as they are only required to clarify the sewage, which without the check afforded by them would be impetuously discharged, together with all its floating matters, into the river. Osier roots also tend to grow down in long filaments, which on reaching the under-drains might find their way inside and block the pipes. Meadow land on the banks of a river has been used for the same purpose, but it would seem that osier beds are preferable, as they more perfectly clarify the sewage.

An even better plan is to set apart a portion of the farm where the land is most porous as a filter bed, specially prepared and closely under-drained six feet deep. The land may be left fallow, or laid out in ridges and furrows and cropped with vegetables. The filter bed should be subdivided into plots for the intermittent application of the sewage, and should be of extent sufficient to purify the whole of the sewage by intermittent downward filtration, when from any reason, such as excessive dilution, it is inadvisable to apply the sewage to the general surface of the farm. Such a filter bed would, of course, add somewhat to the expense incurred in the original construction of the farm, but its great utility would far more than counterbalance its cost, as on all farms, even where storm and subsoil waters are excluded from the sewers, sewage irrigation of land where crops are growing is often attended with considerable risk of injury to the plants. The result is that on sewage farms, as usually conducted, the choice of crops is limited to such as are not injured by the continual application of sewage, and these being produced in excessive quantity often exceed the demands of the local markets, and are consequently almost worthless. If every farm had a filter bed of sufficient area to cleanse all the sewage when not required for irrigation, a variety of produce could be grown under the most favourable conditions, and the kind and quantity of each crop could be regulated, as in ordinary farming, according to the demand for it and the chance of reaping a fair profit by its sale.

There can be no question that, as a general rule, the sewage would be more valuable to the sewage farmer if rain and subsoil water were kept out of it, as the farm would then not be liable to those sudden inundations with enormous volumes of weak sewage which tax the resources of the management to their utmost in their efforts to deal with it. But if this were done, there is the danger of the sewage proving too strong for the crops and requiring dilution, which is especially likely to be the case if the water supply of the town is inadequate to the requirements of the population. In such cases it would be advisable to have at hand some means of diluting the sewage before its arrival at the farm, and this might possibly be effected by turning the water of the subsoil drains into the sewers. At Breton's Farm at Romford during very dry seasons it has even been found necessary to return the pure effluent water into the tanks and mix it with the sewage before applying the latter to the ground in order to ensure the requisite dilution.

There is still another difficulty which remains to be discussed—namely, that which is supposed to arise during severe frosts. But too much stress has been laid upon this; and as a matter of fact sewage irrigation continues uninterruptedly during the coldest weather. It is true that a coating of ice is formed over the surface of the farm, but the sewage, which never has a temperature below 45° F., flows underneath this coating and sinks into the soil, which remains quite unfrozen and open. As soon as the weather begins to moderate, the sewage rapidly melts the ice above it. This is not only the case in this country, but in Germany and America, where the winter cold is far more

intense. Thus at Pullman, U.S.A., a visit paid to the sewage farm in February, 1885, showed that, although for five days previously the temperature had not risen to 0° F., and had been as low as $-25°$, the sewage was going on to the land, but covered by a stratum of ice from 1 to 8 inches thick. On breaking the ice and digging a hole in the ground below with a spade, the soil was seen to be unfrozen and perfectly open. As the weather moderated the sewage rapidly melted the ice above it.[1]

We come now to the consideration of the crops that are best suited for sewage irrigation, and from the growth of which it is most reasonable to expect to derive a profit. A committee of the Local Government Board on Modes of Treating Town Sewage reported as long ago as 1876 that Italian rye-grass is probably in all respects the most advantageous crop to be grown under sewage. Subsequent experience has, we think, fully confirmed the favourable opinion of the committee, and Italian rye-grass is now, as then, the staple product of most sewage farms. Its advantages were stated by the committee to be as follows: 'It is capable of absorbing a larger volume of sewage than any other crop. It occupies the soil so as to choke down weeds, comes early into the market in spring, continues through the summer and autumn, bearing from five to as many as seven cuttings in the year, and producing from thirty to fifty tons of wholesome grass upon each acre.'

It is certainly the fact that plots of rye-grass may be almost continuously treated with enormous volumes of sewage, not only without injury, but even with benefit to their growth. Dr. Alfred Carpenter has stated his belief that this plant possesses the power of absorbing and assimilating the organic matters of sewage directly, unlike plant life in general, for which complex organic bodies must be reduced to such simple constituents as ammonia, nitrates, and phosphates before they can be assimilated. However this may be, there can be no doubt that Italian rye-grass flourishes under a treatment with sewage which would kill most other plants, and that it at the same time very materially aids in the cleansing of the sewage with which it is irrigated.

Although this is the case, the area of land placed under this crop must have some reference to local means of consumption, or the crop, or a part of it, may be wasted. For the grass when cut will neither keep nor bear long carriage, and although in a warm and dry summer good hay may be made from it, or ensilage in a wet season, where silos are at hand, still it is difficult to dispose of such fodder at a profit, owing to cost of carriage. Practical experience has shown that the rye-grass is turned to its most profitable use when used for feeding milch cows or rearing stock. It therefore follows that, should the acreage of the sewage farm justify the experiment, a stock and dairy farm ought to be associated with it. This experiment has been carried to a very successful result at Birmingham. At first there is generally a certain prejudice to be overcome on the part of the consumers in the neighbourhood against sewage-grown produce and the milk and meat from animals fed off it. But this sentiment quickly wears away for want of any reasonable basis. For, as we shall presently have occasion to show, not only is sewage-grown produce neither dropsical nor prone to decomposition, but evidence is entirely wanting to prove that its consumption has at any time caused disease. The meat and milk also of animals reared and kept on sewage farms in no way differs from the milk and meat produced on ordinary farms. We see, then, that Italian rye-grass is likely to be a profit-

[1] *Report of the Mystic, Blackstone, and Charles Rivers Drainage Commission, Mass., U.S.A.*, 1886.

able crop if it can be converted into milk, butter, and meat, and that, under such circumstances, it can be cultivated in large quantities, but that on farms where livestock is not kept it may on occasion prove a drug in the market, and have to be given away.

After three years the plot of rye-grass should be ploughed up, and the land sown with cabbages, swedes, or mangolds. For these, as for nearly all other crops grown on sewaged land, yearly rotation is the best. Cabbage and mangold wurzel were considered by the Local Government Board Committee to be the only farm crops, besides Italian rye-grass, that persistently flourish upon any soils, heavy or light, under continual doses of town sewage. And even these should only be sewaged when growing, and not when they have arrived at maturity. They no doubt help to exhaust the soil of the sewage matters retained in it, which have not been absorbed by the rye-grass. The same committee also stated that no growing crop, save natural grass, should be sewaged during the depth of winter; and for potatoes, turnips, most vegetables, and certainly for all pulse and cereals, the land ought rather to be enriched by frequent irrigation in the preceding season than treated with sewage when these crops are growing, except in times of great drought, and even then care is requisite. There can be no question that fallow land is enriched by irrigation with sewage from retention in the soil of some of its manurial ingredients, just as when solid manures are applied.

From what has gone before, it will be evident that unless a sewage farm is provided with a special filtration area to dispose of the sewage when not required for the fertilisation of the land, or unless the area of land is considerably in excess of that necessary for cleansing the sewage, the crops are practically limited to the three that are not injuriously affected by sewage irrigation when in growth, viz. Italian rye-grass, cabbages, and mangolds, in addition to natural meadow grass and osiers. On such farms, therefore, it would be useless to look for a profit from the sale of produce. But on the farms where a special filtration area is provided, or that have a large acreage for the volume of sewage, not only can numerous other crops be grown with little risk of their being spoilt by the enforced application of sewage, but market gardening even may be undertaken and made very profitable. Italian rye-grass, however, from the peculiar conditions under which only can sewage farming be undertaken—viz. the necessity to purify the sewage night and day, Sunday and week-day, wet weather or fine—must always be the staple crop, and, as we before said, it can only be profitably utilised by employing it as fodder for livestock on the farm itself.

The amount of capital required to stock and work a sewage farm is very greatly in excess of that required for an ordinary farm on the same kind of soil. The Local Government Board Committee stated that five times the usual amount of money would be needed for a sewage farm upon which most of the produce is consumed. There is a far larger amount of labour required to keep the land clean and free from the weeds which the sewage tends to foster, and to take off the land the enormous crops of grass and roots that are grown. But against this must, of course, be set the increased value of the crops over those of an ordinary farm.

We come now to the consideration of the manurial value of the sewage and to the practical results that can be obtained by its use. We have already stated briefly the conditions under which sewage farming may be undertaken with some prospect of success, and we shall suppose that these conditions have been either totally or in large part complied with. It is

now pretty well known that sewage farms are not always or necessarily a success, either in purifying or utilising the sewage; and to establish a farm on heavy clay soil, without sufficient land or without the other essential elements previously alluded to, is merely to court defeat in one or both particulars, and most probably in both.

The water of the sewage is a great difficulty, where no precautions have been taken to deal with excessive quantities of it; but where these have been taken the water has its uses, which counterbalance its drawbacks. It enables the sewage farmer to be independent of drought in dry seasons and to rear large crops of meadow and rye-grass, roots, and cabbages, for the growth and maintenance of which moisture is so essential. In the parched-up land around the sewage farm during a period of drought these crops are failures, and consequently the sewage-grown crops are enormous comparatively in volume, and command a correspondingly high price in the market. Then, again, the water is the vehicle for ammonia and organic matters in solution; and such fertilising matters are more readily absorbed by the roots of plants when in solution in water than in any form of solid manure. The water of the sewage, then, is of use as a fertilising agent, as well as a vehicle for the manurial matters which it carries with it.

As regards these manurial matters of the sewage, we have seen what they are worth theoretically in a ton of sewage both in the form of matters in suspension and matters in solution (see p. 856). What they are worth practically is shown by the statistics of the crops raised on sewage farms, and by a comparison of these statistics with those derived from farms on the same kind of soil where sewage is not applied. It is not possible in this article to examine these figures, but the general result may be stated to be that such crops as thrive under sewage are produced in far larger quantities on sewage farms than on the ordinary farms of the neighbourhood, and are obtained very much earlier in the spring season, no doubt from the warmth of the sewage keeping up the temperature of the soil throughout the cold of winter. What the value of such crops may be has been already the subject of consideration; but it must also be remembered that fallow land is enriched by the application of sewage, and that where this is done in the season preceding the raising of pulse, cereals, or vegetables, it is not necessary to apply solid manures as well, so that a very considerable source of expense is saved to the farmer. It may indeed be stated generally that sewage contains every fertilising ingredient required by any soil, so that artificial or foreign manures can be entirely dispensed with on a sewage farm. If this were not the case it would have been impossible to obtain any produce from those plots of barren sea sand irrigated with sewage, of which the Craigentinny Meadows, near Edinburgh, and the Dantzig Sewage Farm are such striking examples. At Craigentinny enormous crops of Italian rye-grass are produced, whilst at Dantzig the farm has been productive of excellent crops of grasses, roots, and cereals. The latter, indeed, appear to thrive well on this very porous soil when treated with large doses of sewage. It is said to be a truly curious sight here to see, surrounded by irregular dunes of blowing sea-sand, vast spaces covered with a vigorous vegetation as a result of the application of the sewage, which were formerly as barren as the surrounding sand-hills. As another example, we may mention the Plain of Gennevilliers, near Paris, where a barren and unfruitful waste has been turned by means of sewage irrigation into a vast garden, 400 acres in extent, producing flowers, fruit, and a large variety of crops for the Paris market. ('Les Travaux d'Assainissement de Dantzig, Berlin, Breslau,' par M. Durand-Claye.)

The value of sewage is indeed, after all, to a large extent a question of

soil. On rich lands, which are often of a retentive nature, the advantage of further enriching the soil with the manurial matters of the sewage is often more than counterbalanced by oversaturation of the land with water. On poor and barren soils, however, which are moreover usually highly permeable to water, the sewage introduces the fertilisers which are naturally absent, and without which no crops can grow; whilst the excess of water rapidly percolates down to the subsoil, leaving the top soil in the most favourable condition for the growth of plant life. The value of the land, as at Craigentinny and Dantzig, is enormously increased, and what was before a barren waste becomes land capable of cultivation and of producing crops of large value. Here, then, we see sewage utilised to the best advantage, and a noxious waste product converted into a valuable source of food supply.

Having endeavoured to make it apparent that sewage is under certain conditions and circumstances a fertiliser of the soil of the greatest practical value, we can now turn to certain experiments which have been made with the view of estimating the amount of nitrogen recovered in the crops of a sewage farm from the sewage applied to the soil.

These experiments were conducted by the Committee of the British Association on the Treatment and Utilisation of Sewage, and were made upon Breton's Sewage Farm, near Romford, extending over a period of five years (1871–6). The committee ascertained that the amount of nitrogen recovered in the crops during the whole of this period was equal to 32·88 per cent. of the amount applied in the sewage to the surface of the soil, and that the amount recovered per acre of the farm under crop averaged 182 lbs. annually. As was to be expected, the committee found considerable annual variations in the percentage of nitrogen recovered, these variations being dependent upon changes in local circumstances. About 11 per cent. of the total nitrogen applied to the land escaped in the effluent water, but of that only a fractional percentage was in an organic form, the largest proportion existing in the oxidised form of nitrates. About 56 per cent. of the nitrogen applied in the sewage is unaccounted for, but of this a portion must have been retained in the soil of the farm, which it served to enrich. For it was found on comparing the analysis of the average composition of the soil of the farm, made previously to the application of sewage, with a similar analysis made in 1873 that the phosphoric acid in the soil was increased nearly sixfold—viz. from 0·01 to 0·058 per cent.; the loss on ignition of the soil was much greater (leaving water out of the question); the amount of ammonia had increased from an inappreciable quantity to 0·016 per cent.; and the amount of nitrates had also increased.

These results the committee considered highly satisfactory (especially when the extreme porosity of the soil and limited area of land available for irrigation are taken into account), as in the experiments of Messrs. Lawes and Gilbert only from 40 to 60 per cent. of the nitrogen applied in solid manures was recovered in the crops within the season of application. The committee also called attention to the very careful way in which the samples were taken and submitted to analysis, the results obtained for the sewage and effluent water being as absolute and exact as accurate gauging and careful analysis could make them, and those for the crops calculated by means of the most reliable published data. The observations also cover a larger area of land and a greater variety of crops than have ever hitherto been scientifically made. As regards the samples of sewaged soil, they were very carefully taken at the same part of the farm as the samples had been taken before the application of sewage, and were mixed to form an average sample for submission to analysis.

It was at one time thought that sewage when exposed to the air in open carriers on sewage farms would lose a large proportion of ammonia, its most valuable fertilising ingredient. The researches of the Rivers Pollution Commissioners, however, have shown that this is not the case. On exposure of a solution of carbonate of ammonium, 9·25 parts in 100,000, in a layer of only 2 inches deep, to a strong draught of air for three days, the solution at the end of this time still contained the same proportionate amount of ammonia —that is to say, it lost ammonia precisely in proportion to the evaporation that took place; or, in other words, the difference between the volatility of the ammonia and that of the water in such solution and after such a time is, under the most favourable conditions, inappreciable. Seeing that the sewage in an open carrier would generally be deeper than 2 inches, there is no reason to fear any appreciable loss of fertilising effect from the evaporation of its contained ammonia during a flow through even a great length of conduit.

It is true that the evaporation of water from the surface of a sewage farm is enormous in amount. The British Association Sewage Committee found that, on an average of over a year's (399 days) observation, only 47·3 per cent. of the sewage pumped on to Breton's Farm was discharged through the deep drains as effluent water. The rainfall at the farm during the period of observation, being 22·64 inches, introduced on to the land the equivalent in water of 235 days' flow of sewage, so that the amount of evaporation from the surface of the land is seen to be enormous. But at the same time it must be remembered that some of this water is not evaporated at all, but is absorbed by growing vegetation, whilst that which is evaporated must be to a large extent given off by the leaves of plants, which give off water but not ammonia; so that there is no reason to suppose that excessive evaporation means a great loss of ammonia.

We may conclude, then, both from a consideration of the practical farming results attained, and of the experimental investigations that have been made, that sewage is in every sense a valuable manure, for it enriches the soil and gives up some of its fertilising ingredients to the crops growing on sewaged land, these ingredients being to a notable extent those which vegetation exhausts from the soil, and which it is the *rôle* of manures to resupply in a form capable of easy assimilation and absorption.

We come now to the consideration of the character of the effluent water from sewage farms, and to inquire what degree of purity such waters exhibit under different local circumstances. From what has been previously stated, it will be evident that the effluent water exhibits its highest degree of purity when the sewage percolates through the soil, and is not applied too continuously, nor in too large volumes to each plot of land. The following analyses were made by the Sewage Committee of the British Association on Breton's Sewage Farm, near Romford, where the soil is of a porous nature, and the sewage is very efficiently filtered by percolation through the soil. The analyses represent the average composition of the sewage pumped on to the farm from March, 1872, to March, 1873, and of the effluent water escaping from the deep drains. It is important to note that these analyses were made of average samples—that is to say, of samples taken in proportion to the rate of flow of the sewage at the time, as indicated by the gaugings. But in comparing the analysis of the sewage with that of the effluent it must be remembered that about two volumes of sewage are concentrated by evaporation into one volume of effluent, in spite of the addition of the rain water to the latter, for, as before stated, only 47·3 per cent. of the sewage applied to the land escapes from the deep drains as effluent water. As regards the

effluent water, then, a very considerable correction is necessary to rectify the result, if the comparisons of sewage and effluent water are to be made according to the respective volumes of each, by placing the evaporated water to the account of the effluent.

Results given in parts per 100,000.

Nitrogen						
	In Solution				In Suspension	Total in Solution and Suspension
—	As Ammonia	Organic	As Nitrates and Nitrites	Total		
Sewage . . .	2·6	1·05	0	3·65	1·75	5·4
Effluent . . .	0·072	0·147	0·947	1·166	0	1·166

From these analyses it will be seen that a large proportion of the nitrogen in the effluent exists in the form of the innocuous residues, nitrates and nitrites.

The Rivers Pollution Commissioners have also recorded analyses of sewage and effluent from sewage farms, of which we may cite one example. At the Lodge Farm, near Barking, where the soil is a pervious gravel, the organic nitrogen was reduced from 3·664 parts in 100,000 of the sewage to 0·329 parts in 100,000 of the effluent water; the ammonia was reduced from 4 to 0·8 part per 100,000, whilst nitrates and nitrites, which were absent from the sewage, appeared in the effluent water to the extent of nearly 3 parts per 100,000.

It would be possible to quote other analyses pointing in the direction of a very highly purified effluent as the result of irrigation under favourable circumstances. But it will be enough here to sum up the general results as follows:—All the constituents of sewage are greatly reduced by irrigation, with the exception of chlorine, which is very slightly reduced, or even sometimes apparently increased, owing to the concentration effected by evaporation; but the constituents which are most effectually removed from the sewage are especially the putrescible organic matters—those, namely, which it is essential to remove both from an agricultural and sanitary standpoint. Nitrates and nitrites do not exist in the sewage, but are usually found in the effluent water to some extent, and are evidence of the oxidation processes to which the sewage has been exposed in the soil.

As a rule, then, it may be taken that nitrates and nitrites are found to a considerable extent in all well-purified effluents, and that their absence indicates deficiency of oxidation and inability on the part of the soil to properly cleanse the sewage.

As regards farms on which surface-flow, and not filtration, chiefly takes place, the effluent is not so well purified. Such farms are those in which, there being a somewhat retentive soil, systematic under-drainage has not been carried out. But even here, when the amount of land is sufficient, the oxidation by surface flow, and the retention and absorption of putrescible matters by growing plants, are usually capable of producing an effluent—not indeed highly purified, but quite sufficiently pure to enter the watercourses of the locality. If in such cases the land is totally insufficient in area, it speedily becomes water-logged to such an extent that the sewage flows over it and passes away almost unpurified into the streams. But such instances cannot be taken as examples of properly conducted sewage farms, and are condemned alike by advocates and opponents of sewage irrigation.

Where the soil of a farm is very clayey and retentive, filtration is an impossibility; and in such cases surface flow must be entirely relied upon, and under-drainage is liable to do more harm than good, for the reason that in dry summers large cracks and fissures form in the soil, so that the sewage passes away directly from the surface of the ground to the under-drains without having been purified at all, and is discharged in this condition into the streams. Under certain conditions surface-flow may be relied upon to give a fairly pure effluent, and we cannot do better than quote the Wimbledon Sewage Farm as an example.

Here the sewage of about 25,000 people is first precipitated with lime, lime and herring-brine, or lime and sulphate of alumina. The clarified effluent from the tanks is applied to sixty-six acres of land, consisting very largely of stiff clay soil. The sewage is thus seen to be applied in the proportion of about 380 persons to each acre. The sewage flows from one carrier to another over the land on the catchwater system, such purification as it receives being entirely due to surface flow and not to filtration. There is no under-drainage, such under-drains as formerly existed having been taken out of the ground and removed. The land is extensively planted with Italian rye-grass and osiers, but cabbages and mangolds are also grown on ridges, and are well sewaged. The sewage first passes over successive plots of rye-grass and finally over an extensive osier bed before reaching the river Wandle. On the occasion of our visit the effluent, as it passed into the river, was clear, colourless, and inodorous, and apparently in a perfectly fit state to be discharged into the stream. There is a storm overflow to the outfall sewer, which discharges the storm waters and sewage after heavy rainfall on to an osier bed, where some of the suspended matters are kept back from the sewage before it reaches the river. The satisfactory result attained at Wimbledon is no doubt largely due, first, to the removal of the suspended matters of the sewage by precipitation in tanks, and secondly, to the comparatively large area of land available for irrigation, and to the care with which the land is kept cropped; but even here we should expect that in winter the purification would be less efficiently performed than in the warmer months, as during the cold season plant life and activity are in abeyance. This was found by the British Association Committee to be the case on the Beddington and Norwood Farms when visited in winter. The rye-grass yields an average of five cuttings in a season, and is bought by farmers in the neighbourhood, who cart it off the land.

It will be necessary at this point to allude to the so-called 'sewage fungus' (*Beggiatoa alba*) which is so frequently found growing on the sides of the carriers on sewage farms, in the effluent water channels, and on submerged objects in the streams into which the effluent passes. This fungus was formerly held to constitute, when found on the banks of rivers, evidence of the pollution of the water with sewage or with an unpurified effluent. But, inasmuch as this fungus feeds largely on sulphur, which it extracts from mineral sulphates as well as from decomposing organic matters, it is found at other places than in sewage-polluted waters, and is therefore in no way diagnostic of sewage pollution. Even the most highly purified sewage effluent will contain abundance of mineral sulphates, so that *Beggiatoa alba* is likely to be found in all waters into which such effluents are discharged. It cannot, then, be held to indicate the presence of putrefiable organic matters in the water of streams in which it is found, but merely of an abnormal amount of sulphates. There seems no reason either to believe that it has itself any injurious effect on the water, except when found in large quantities, when

the fungus may cause nuisance by rotting in the water and giving off offensive gases.

The influence of sewage farming upon the public health, either as being productive of nuisance or actually causative of disease, must next arrest our attention. It will be convenient to consider the question of nuisance in the first place.

There cannot be the slightest doubt that badly managed sewage farms may give rise to a very serious nuisance in their immediate neighbourhood. The nuisance may be due to one of several causes :—(1) The sewage may arrive at the farm in a putrid condition owing to the length of time it has been retained in old and dilapidated or badly constructed sewers. The application of such foul liquid to a large surface of land is pretty certain to give rise to offensive effluvia, which will be the cause of complaint. (2) If ditches dug in the soil are used as the permanent carriers, much of the solid matters in the sewage will be deposited on their sides, and if this sediment is not removed or dug into the ground, it will putrefy and give off offensive gases. (3) Where too much sewage is applied to land consisting of clayey soil, the sewage ponds on the surface and the stagnation lead to putridity with its offensive accompaniments.

In all these cases it is obvious that proper dispositions have not been made or that the management is at fault. The remedies indicated are (1) the flushing or reconstruction of defective sewers, so that the sewage may arrive at the farm in a fresh and undecomposed condition ; (2) the adoption of permanent carriers of stoneware or concrete, which can be easily flushed and cleansed ; (3) the acquisition of a larger area of land, and the breaking up and close under-drainage of that which is too impervious to admit of a proper amount of filtration of the sewage.

As regards carefully conducted sewage farms, there is very little evidence that nuisance is caused to the neighbourhood. In dealing with so foul a liquid as town sewage it is impossible to avoid all odour at all times and at all places ; but considering the number of sewage farms that now exist, dotted all over the country, the fact that complaints from residents in their neighbourhood are so infrequent as they are, is very valuable testimony that sewage irrigation is productive of very little nuisance. To take only the case of the Croydon Sewage Farm at Beddington, we learnt from the late Dr. Alfred Carpenter that the locality around part of the farm has become a residential neighbourhood, and that the value of land and the price of property on the immediate borders of the farm have risen enormously in recent years. There are no complaints of offensive smells at Norwood; a public foot-path through the irrigated fields is used as a pleasure walk by numbers of people, many of whom are unaware of the character of the farm over which they are passing.

There is, too, but very little evidence of disease being caused even by badly conducted sewage irrigation. An outbreak of dysentery and diarrhœa in 1864–5 amongst the patients of the Cumberland and Westmoreland Asylum was recorded by the medical officer (Dr. Clouston) as being due to the sewage farm which was in close proximity to the asylum. But here it seems that strong and putrid sewage became ponded on the irrigation plot, forming a filthy morass. Sewage is still applied on the grounds of this asylum, with the difference that the irrigation is conducted on proper principles ; and from 1874 to 1887 Dr. Campbell, the present medical officer, has found no disease or nuisance in any way arising from the distribution of the sewage.

There is, besides, evidence to show that the men who work on sewage

farms, and their families who reside there, exhibit a very low rate of mortality, and are quite as healthy as the labourers on ordinary farms. From the returns of nine sewage farms which were in competition for the Royal Agricultural Society's prizes it appears that the death-rate amongst the residents on the farms, on an average of the number of years which they have been in operation, does not exceed 3 per 1,000 per annum. This rate is very likely not lower than that which would obtain amongst ordinary agricultural labourers, but still it shows that sewage farming is not detrimental to health or life.

Epizootic and entozoic diseases amongst cattle have not been shown to have been originated or favoured in their spread by sewage irrigation. The late Dr. Cobbold, as long ago as 1865, published some considerations which induced him to believe that sewage farming would tend to spread entozoic disease both amongst men and cattle. With the view of testing the soundness of the indictment thus preferred by Dr. Cobbold, the British Association Sewage Committee subsequently made a very careful investigation of the subject in conjunction with Dr. Cobbold himself, but they failed to trace any such connection. The committee found that on one farm there was a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers to entozoal larvæ, and without which the cycle of their existence cannot be continued; and they also pointed out that alkaline sewage probably destroys organisms whose natural habitat is the acid secretion of the human intestines, and, if so, they must be destroyed in the sewage before they arrive at the farm. It has also been recorded that wire-worms (*Oscinis vastator*), which do so much injury to cereal crops, have been entirely destroyed by dressings of sewage applied to the affected plants.

It may be stated, then, that the consumption of sewage-grown produce, whether by men or beasts, has never been shown to be a cause of parasitic disease in either, and that there is no probability of its being ever likely to prove so. As regards the feeding of cattle on irrigated meadows, it certainly seems more cleanly to allow the sewage to sink away into the soil before admitting them on to the land, though there seems to be no appreciable risk incurred by a contrary practice.

Subsoil Irrigation

For the disposal of the sewage of towns surface is preferable to subsoil irrigation. The utilisation is more complete, the purification is more certainly ensured, and surface carriers are more easily cleansed than underground drains. But for isolated houses and groups of houses in country districts, where the purification of the sewage would have to be effected on land adjoining inhabited premises, it is often advisable to have recourse to subsoil irrigation in preference to the other method. Subsoil irrigation can also be relied upon to purify the slop waters of houses in country districts where some form of dry closet is in use for the disposal of the solid human excreta.

The slop waters of villages are but little less impure than water-closet sewage, and are usually got rid of in rural districts by being allowed to pass into ditches or streams; they are undoubtedly productive of considerable nuisance. They contain, however, somewhat less of solid floating and suspended matters than water-closet sewage, so that, whereas it is advisable to strain the latter liquid to remove the larger solid bodies before using it for sub-irrigation, such a proceeding is not required for the cleaner slop waters.

A very small piece of ground only is required to purify the slop waters of a single cottage or small house; but in the case of a village, where the houses are in fairly close proximity, it would probably be better to adopt a combined system and to carry the slop waters of the whole village in a pipe sewer to a piece of land outside. Larger houses standing in good-sized grounds could purify their slop waters or sewage on their own premises, and would probably find it advantageous to do so, as the liquid manure when applied to the land would no doubt considerably increase the garden produce.

The plot of land chosen for sub-irrigation should be of a light and porous character, to ensure the efficient filtration of the sewage liquid, and should, if possible, have a gentle steady slope. To avoid the necessity of pumping, the plot of ground should be, if possible, at a lower level than the house or houses from which the sewage flows. At a depth of from 6 to 12 inches from the surface of the soil should be laid a systen of 2-inch porous earthenware pipes, placed about 5 or 6 feet apart, with open joints between the lengths of pipe (each pipe being about a foot in length). The ends of the pipes should be supported upon cradles, made of half pipes, and protected above by similar covers, to allow for the escape of the water and to prevent earth getting into the pipes (figs. 183 and 184). The system should be connected at its highest end with the water-tight drain conveying the sewage to the land, and from this point the pipes should have a slight fall away of 6 or 8 inches in 100 feet, and should ramify under the soil over the entire area of the plot.

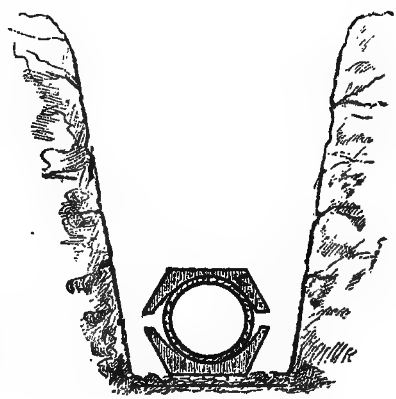


FIG. 183.—Drains for sub-irrigation.

Where the soil is very porous no further drainage is required; but with the more retentive soils it is advisable to lay a drain at a short distance from the ends of the pipes to collect the effluent water and convey it into the watercourse.

FIG. 184.—Sub-irrigation drains.

It is now usual in the case of single houses to collect the slop waters or strained sewage in a siphon flush tank (fig. 185), which discharges its contents automatically at regular intervals into the sub-irrigation drains. The reason for doing so is that the waste waters passing away from a single house flow in a mere dribble, so that the liquid penetrates but a very short way along the sub-irrigation drains, and the pipes become in time choked with deposited sediment. That portion of the sub-irrigation plot, also, which is nearest the house-drain receives very much more than its proper share of the irrigating liquid, so that its cleansing properties become speedily overtaxed.

The flush tank (fig. 185), on the other hand, stores the dirty water until a considerable volume is collected and the tank is full, when it suddenly

discharges its contents, which escaping in large volume with a high velocity reach every part of the sub-irrigation plot. By this means, then, each portion of the land receives its due share of the irrigating liquid, and receives it intermittently—viz. at such periods only as the tank discharges, which, of course, depend on the capacity of the tank in relation to the volume of water it receives in the twenty-four hours—and purification and utilisation are thereby greatly facilitated. The tank now in most general use is that fitted with Rogers Field's annular siphon arrangement. This tank in practice is found to work very well: a very small dribble of water only is required to start siphonage when the tank is full; and 'dribbling' and 'continuous action'—by which is meant that when the tank is full, water dribbles continuously down the discharge pipe as fresh water enters the tank, but the tank does not properly siphon itself—are not found to occur if the tank is placed on a perfectly level surface with the discharge pipe quite plumb.

The sewage or slop waters should be conveyed to the sub-irrigation plot by a greater or less length of water-tight drain, according to circumstances.

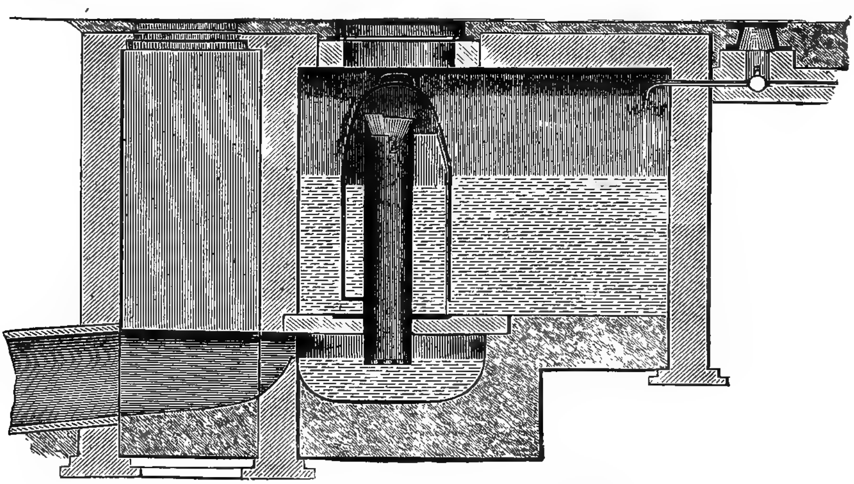


Fig. 185.—Field's automatic siphon flush tank.

When the liquid reaches the porous drains it very rapidly escapes through the open joints between the lengths of pipe into the soil, where some of its polluting ingredients are absorbed or assimilated by the roots of the grasses and other vegetables grown on the plot, and the remainder are purified by oxidation and nitrification as the water percolates more deeply into the soil. The purifying agencies are the same as in intermittent downward filtration, of which, indeed, subsoil irrigation is merely a variety, the irrigating liquid being applied a few inches beneath the soil instead of from the surface. In like manner, also, the effluent water escapes from the drains, free from all polluting organic constituents (provided the area of the sub-irrigation plot is sufficiently large to absorb and cleanse the sewage applied to it), and may at once be allowed to pass into the nearest watercourse. If the soil is very porous, the effluent water may be entirely lost in it by percolating deeply until it reaches the subsoil water.

The sub-irrigation drains may require to be taken out of the soil, and any deposit that has collected in them removed before they are relaid, about once in five years or more, according to circumstances.

THE DISPOSAL OF MANUFACTURING REFUSE

In manufacturing districts the pollution of streams is probably quite as largely due to the discharge of waste waters from factories as to the entrance of house sewage into the river waters. These waste liquors are in many cases of a highly polluting character, containing organic refuse of various descriptions, or poisonous metallic compounds, which kill the fish in the river and effectually put a stop to the natural processes of oxidation which are capable of repurifying polluted waters under certain conditions (see p. 851). The spent liquors from dyeing works may give the water a black or dark-coloured appearance, so that rivers polluted with manufacturing refuse are often as objectionable to sight as they are to smell and taste. Of the offensive condition of many streams in the North of England much evidence will be found in the reports of the Rivers Pollution Commission.

There can be no doubt that town sewage is far easier to deal with, having regard to its purification and utilisation, when unmixed with manufacturing refuse, which often contains strong acids or alkalies or other poisonous residues, and are exceedingly injurious to vegetation when the sewage is applied to land. On the other hand, it is impossible for municipal authorities to exclude such waste matters from the sewers, and it is difficult to see how the manufacturers themselves could efficiently purify their waste liquids on their own premises, which are often of very limited extent, when situated within the town boundaries.

The Rivers Pollution Commissioners expressed the opinion that 'for populous places which are also seats of manufacture it would generally be possible, without materially complicating the sewage problem, to allow the fluid refuse of industrial processes with few exceptions to pass into the sewers to be disposed of as common sewage, the special exceptions being the refuse of workers in metals and of manufacturers of gas, paraffin oil, pyroligneous acid, and animal charcoal; that, subject to some such exceptions as these and to proper regulations, the discharge of fluid industrial refuse into sewers would generally not render the sewage more difficult of use, and would in some cases, in respect of certain contained refuse matters, greatly increase the agricultural value of the sewage.' For instance, the waste liquor from flannel works is exceedingly rich in ammonia and organic matters, that from works at Newtown being found to contain in 100,000 parts no less than 1733·4 of suspended organic matters, 446·353 of dissolved organic carbon, 91·185 of dissolved organic nitrogen, and 80·012 of ammonia. But such cases of enrichment of sewage are probably exceptional, and cannot be held to contradict the truth of the statement that sewage is easier to treat when unmixed with industrial refuse.

Probably the best means of dealing with the sewage of manufacturing towns is that pursued at Birmingham, of which mention is made at page 864. The preliminary precipitation with lime carries down many of the compounds which would prove deleterious to vegetation, and neutralises the acidity arising from the presence of free acids or acid salts in the sewage. The clarified and alkalinised effluent from the tanks can then be applied to land with every prospect of attaining a successful result, both as regards its purification and its utilisation in the production of crops.

For factories situated away from towns, where no outlet for waste waters into town sewers is possible, it would, as a rule, be desirable to resort to intermittent downward filtration upon a specially prepared and under-drained plot of land in the vicinity of the works. In most cases it would probably

be useless to attempt to raise crops on the filtration area, as the waste liquors, even if they contain valuable manurial ingredients and are free from poisonous salts or residues, usually contain these matters in too high a proportion, with the result that only weeds and coarse grasses flourish on the irrigated land, the finer produce being injured or killed. A preliminary precipitation of the waste waters with lime would no doubt tend to a more successful result in the way of rearing produce, but the cost would probably be prohibitive, and the ultimate cleansing of the dirty water would be but little enhanced. It would, however, appear to be desirable in the case of acid wastes to neutralise the liquid with lime without attempting to precipitate it, otherwise nitrification of ammonia and organic matters in the surface layers of the soil may be very greatly diminished, owing either to the destruction of the nitrifying organisms themselves, or to the absence of the salifiable base which should be present in the soil for the nitrous and nitric acids, when formed, to combine with.

It has been amply demonstrated that intermittent downward filtration carefully carried out on a suitable soil is capable of purifying the very foulest specimens of industrial waste waters, and this is then the method which should be everywhere employed where land of suitable quality and extent can be obtained. If it is found impossible to acquire the necessary land, then an attempt should be made to precipitate the suspended matters in tanks by means of lime or other chemical substance, and to further purify the effluent by intermittent filtration through banks of coke, cinders, or ashes. In this way it will be possible to procure a colourless and clear effluent, which, if not entirely free from soluble polluting ingredients, is at least incapable of doing much injury to the water of the stream into which it is discharged.

THE INFLUENCE OF SANITARY WORKS UPON PUBLIC HEALTH

It is perhaps hardly necessary at the present time to recapitulate the evidence as to the beneficial effect upon the public health of the works of sewerage, drainage, and water supply, which have been so marked a characteristic of the social progress of the latter half of the present century. It is pretty generally recognised now that filth and disease stand to each other as cause and effect; but inasmuch as there is a tendency to forget facts which are not presented to us constantly in every-day life, a brief *résumé* of the subject may not here be out of place.

Although accurate statistics are not available until civil registration began at the commencement of the present reign, we can picture to ourselves fairly correctly the condition of the public health in the seventeenth and eighteenth centuries. In 1593 was commenced the system of registration of births and deaths by the parish clerks of London from which we get a knowledge of the causes of death, although it is impossible to construct death-rates, there being no enumeration of population. That the death-rate during two centuries—1600 to 1800—must have been excessive, we know from the large proportion to the total mortality of deaths from zymotic diseases, ague, and consumption, which invariably indicate a high general death-rate. So high, indeed, was the death-rate that the annual deaths invariably exceeded the births in London, and the population was only prevented from diminishing by immigration from the rural districts. Ague, dysentery, and consumption figured largely in the mortality bills, and the mortality amongst infants and young children was enormous. Typhus, small-pox, and measles caused a

large number of deaths, and in the sixteenth century plague and sweating sickness were epidemics causing an enormous mortality, and even decimating the population in certain years. Even in years when plague was absent, preventable fevers alone probably accounted for at least one-quarter of the deaths.

The causes of the excessive mortality must be sought in the filthy condition of the city itself. The streets were unpaved, or paved only with rough cobble stones. There were no sidewalks. The houses projected over the roadway, and were unprovided with rain-water gutters, so that during a shower the rain fell from the roofs into the middle of the street. The streets were filthy from constant contributions of slops and ordure from animals and human beings, any system of scavenging being unknown. There were no underground drains, and the soil of the town was soaked with the filth of centuries. This sodden condition of the soil must have affected the wells to a considerable extent. The streets were filthy without, the houses were filthy within. The rooms of the poor were more like pigstyes than human habitations, unventilated and strewn with rushes, which were seldom changed, and the wretched inhabitants closely packed in these miserable hovels must have been very prone to suffer from infection of all kinds. The city, too, was surrounded with marshes, and this fact accounts for the exceeding prevalence of ague and dysentery.[1]

Coming now to the present century, the sanitary condition of houses and towns forty or fifty years ago all over the country was far superior to that described as being characteristic of ancient London. But the system which was then almost everywhere prevalent of collecting large accumulations of human refuse in cesspools and midden pits, the consequent pollution of well waters, and the absence of any proper scavenging arrangements, caused still a high mortality amongst the population generally, and a very considerable endemic prevalence of enteric fever, not to mention occasional outbreaks of cholera and other diseases, invariably dependent upon faulty methods of refuse disposal. The reports of the Health of Towns Commission, 1844–5, and of the Sewage of Towns Commission, 1861, drew forcible attention to these faulty conditions as being the causes of much preventable sickness and mortality, and their publication stimulated local sanitary authorities to undertake those works of sewerage, drainage, and water supply which were so urgently needed in the interests of improved public health.

The great improvement in health, as evidenced by lowered death-rates, which followed the execution of these sanitary works, is very fully brought to light in a report by Dr. Buchanan 'on the results which have hitherto been gained in various parts of England by works and regulations designed to promote the Public Health' (Ninth Report of the Medical Officer of the Privy Council, 1866). Twenty-five towns, of very different populations, were chosen to illustrate the effects of improved sanitation, these being the towns where at that time structural sanitary works had been most thoroughly done, and had been longest in operation. The nature of the sanitary operations carried out in these towns was as follows:—A. Drainage works affecting surface, subsoil, or houses. B. Improvements in water supply—amending previous sources or substituting or adding new ones. C. Measures designed for the removal of decomposing organic matters or for preventing contamination of air or water thereby, viz. 1. The substitution of water-closets for cesspools and middens. 2. The improvement of middens. D. Improved paving, scavenging, and public cleanliness. E. Amendments of the lodg-

[1] *London, Ancient and Modern, from a Sanitary Point of View.* By Dr. G. V. Poore.

ment of the inhabitants, the regulation of common lodging-houses, and the repression of overcrowding.

Of these towns, twenty exhibited a reduction in the death-rate for the period after the completion of the sanitary works as compared with a certain period before the works were commenced. The reduction was greatest in the cases of towns like Cardiff and Newport (32 per cent. reduction, or omitting cholera 23 per cent.), where the previous death-rate was very high from the existence of notable sanitary defects; and was least in towns like Bristol, where the previous death-rate was not excessive.

The reduction of the death-rate from enteric (typhoid) fever is especially noteworthy. In nine towns the reduction exceeded 50 per cent., being highest in Salisbury, where the former rate of 0·75 per 1,000 was reduced to 0·175 per 1,000—a reduction of over 75 per cent. In ten towns the reduction varied between 33 and 50 per cent.; in two there was a trivial reduction, and in three (Chelmsford, Penzance, and Worthing) more or less increase. The reason of the increase in these three towns is explained by the fact of insufficient ventilation of the sewers, combined with backing up of sewage in them, so that sewer gases found their way into the houses.

It is instructive to follow up the decreased rates in these towns by a reference to the rates exhibited in modern years, the interval between 1866 and the present time being no doubt occupied in perfecting the sanitary works which had at the former period only recently been completed. We can take the cases of Cardiff, Leicester, and Bristol, which are three of the large towns the statistics of which are published in the reports of the Registrar-General.

—	General Death-rate per 1,000			Enteric Fever Death-rate per 1,000		
Cardiff . . .	1847–54 33·2	1859–66 22·6	1884–8 23	1847–54 1·75	1859–66 1·05	1884–8 0·40
Leicester .	1845–51 26·4	1862–4 25·2	1884–8 20	1845–51 1·45	1862–4 0·77	1884–8 0·22
Bristol . .	1845–7 24·5	1861–2 24·2	1884–8 18·9	1845–7 1·0	1861–2 0·65	1884–8 0·14

It will be seen that, except in the case of Cardiff, where an altered social condition of the population may account for the discrepancy, the general death-rates of the towns have been much lowered in recent years. The lowering of the enteric fever death-rate is even more remarkable, and should be still more apparent than is shown by the tables; for the rates for the period 1884–8 are for 'fever,' which includes typhus and simple continued fever as well as enteric. Typhus and simple continued fever formed 17 per cent. of the mortality from 'fever' in England and Wales during the period in question (1884–8), so that 17 per cent. of the rates given under this head for the three towns in the table should be deducted to render the comparison complete.

That these three towns are not exceptional instances is shown by the fact that the whole country exhibits a similar decrease in enteric fever mortality during the corresponding period (see diagram, p. 893). In 1869 (the first year in which enteric fever returns, as separate from 'fever,' are obtainable) the death-rate from enteric fever in England and Wales was 0·39 per 1,000 of the population, and has steadily declined to the present time, the death-rate in 1887 and 1888 being only 0·182 per 1,000 and 0·169 per 1,000,[1] a reduc-

[1] In 1889 the enteric fever death-rate was 0·173 per 1,000; in 1890 it was 0·179 per 1,000.

tion of over 50 per cent. in less than twenty years. The curve in the diagram is interesting as showing the rapid decrease in 1876 and 1877, which following as it did upon the passing of the Public Health Act of 1875, and the appointment of medical officers of health throughout the country, is sufficient evidence of the beneficial results that can be obtained by sanitary improvements—more especially of those which have for their object the removal of excreta by water carriage and the introduction of a pure water supply.

The same fact is brought to light in a rather different way by the accompanying table, page 894, which is taken from the Fifty-third Annual Report of the Registrar-General, 1890. From this table it will be seen that forty years

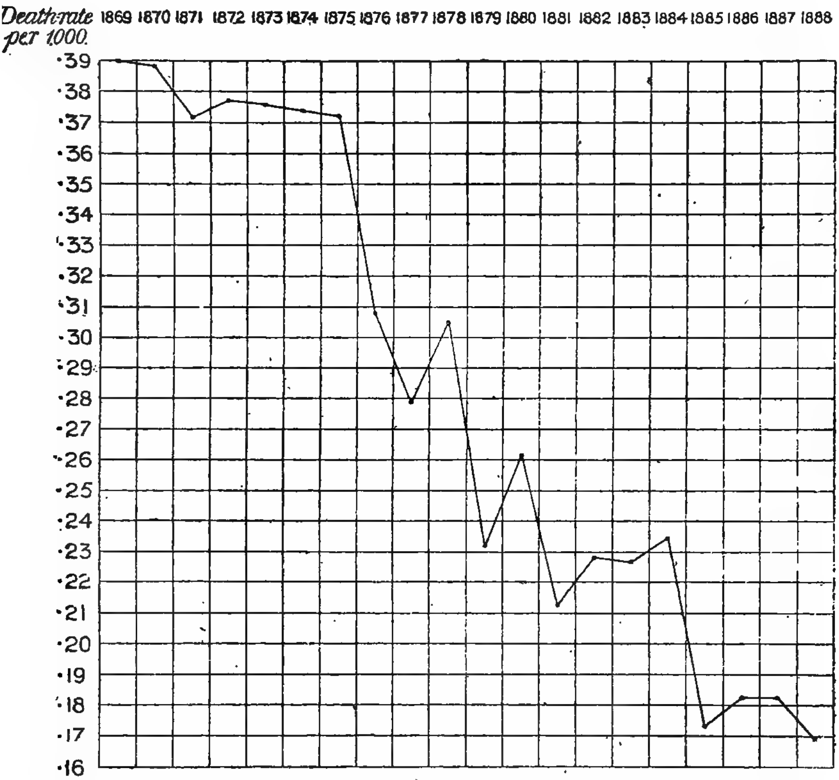


FIG. 186.—Curve showing death-rate from enteric (typhoid) fever in England and Wales from the year 1869.

ago the general death-rate in urban districts was considerably in excess of the rate current in rural districts. Both rates have declined, but the urban death-rate to a considerably greater extent than the rural death-rate, for the reason that sanitary works and measures have been prosecuted to a far greater extent in towns than in the country, and the town populations have consequently derived a greater advantage from sanitary improvements than the rural communities. The difference in death-rate between town and country, although really greater than here shown, owing to absence of correction of the rates for the differing age and sex distribution in the respective populations, is seen to be but slight at the present time as compared with the differences in earlier years, when the sanitary conditions under which rural populations existed were immeasurably superior to those of the town populations.

Illustrations of the effect of sewerage on the diminution of enteric fever

—	Death-rate per 1,000 living in			Death in Town Districts to 100 Deaths in Country Districts in equal numbers living
	England and Wales	Town Districts	Country Districts	
1851–60	22·2	24·7	19·9	124
1861–70	22·5	24·8	19·7	126
1871–80	21·4	23·1	19·0	122
1881–90	19·1	20·3	17·3	117
1881	18·9	20·1	16·9	119
1882	19·6	21·0	17·3	121
1883	19·6	20·7	17·9	116
1884	19·7	20·9	17·6	119
1885	19·2	20·1	17·8	113
1886	19·5	20·4	18·0	113
1887	19.1	20·2	17·2	117
1888	18·1	19·0	16·6	114
1889	18·2	19·3	16·4	118
1890	19·5	20·9	17·4	120

prevalence and mortality may be taken from abroad as well as from English cities. A very striking example is furnished by Munich,[1] which, prior to the year 1880, when the city drainage was completed, was a city standing on ground riddled with porous cesspools. From 1866 to 1881 the average yearly admissions of enteric fever to hospital were 594. In 1880 the admissions were 492, but fell in 1881—the sewerage works being then completed—to 99; and from 1881 to 1888 the yearly admissions average only 104, or little more than one-sixth of the number admitted annually prior to the drainage works. From 1866 to 1880 the average number of deaths from enteric fever in a year was 208; from 1881 to 1888 the average yearly number was only 40. From 1866 to 1888 the population of Munich has nearly doubled, showing a rise from 152,000 in 1866 to 278,000 in 1888, so that the enteric fever rates per 1,000 of the population in the pre-drainage period were 3·32 (hospital admissions) and 1·15 (deaths) and in the period subsequent to drainage 0·42 and 0·16 respectively. This great result is to be ascribed almost exclusively to the sewerage of the city and not to the introduction of a new supply of water from a distance, for the sudden lowering of the enteric fever mortality took place in 1881, soon after the completion of the sewerage system, whereas the improved water supply was not carried out until some years later.

A not less important result than the diminishing prevalence and fatality of enteric fever is the practical extinction of cholera in this country. There has been no cholera epidemic in this conntry since 1866. The absence of this terrible scourge can hardly be attributed to want of opportunity, for on several occasions cholera infection has reached our ports, but must rather be looked for in the improved sanitary conditions under which the town populations now exist, so that the contagion even if introduced fails to establish a footing, and disappears for lack of those filth-engendered conditions under which alone can it exert its powers of propagation. The epidemic of 1866 was mild in comparison with that of 1854, and this in its turn caused a far less mortality than its forerunner of 1848–9. All the twenty-five towns examined by Dr. Buchanan showed this reduction, and in many cases the epidemic of 1866 passed them by altogether, although the previous outbreaks had been productive of a high mortality.

The mortality from diarrhœa was found to be greatly reduced in many towns where sanitary improvements had been effected, but the reduction

[1] *Münchener neueste Nachrichten.* By Professor von Ziemssen, 1889.

was by no means so universal as in the case of enteric fever, and in some cases the mortality had increased no doubt as the result of an altered age distribution of the population, a high birth-rate causing an increased proportion of infants and young children in the population, on whom principally diarrhœa exerts its effects.

Scarlet fever, measles, and whooping cough appear to have been but little influenced as causes of death by the improvements in sanitary condition consequent upon the execution of works of sewerage; whilst of croup and diphtheria Dr. Buchanan reported that they had increased in almost all the twenty-five towns during or after the completion of their sanitary works, and in many cases diphtheria seemed to have appeared during these alterations and to have increased after them. Since the date of Dr. Buchanan's report (1866) diphtheria has been steadily increasing as a cause of death in most of our large towns. It was formerly regarded as being to a far greater extent a rural than an urban disease; but this view can no longer be entertained when it is stated that the death-rate in London from this disease alone was 0·37 per 1,000 in 1889, and 0·33 per 1,000 in 1890, and that it figures almost if not quite so largely now as a cause of death in the weekly records as measles and whooping cough, and far exceeds scarlet fever. A satisfactory explanation is still wanting of this increasing mortality, but it is certain that diphtheria is little influenced by the sanitary improvements which have so marked an effect upon enteric fever.

One other disease remains to be mentioned as having been very greatly influenced in fatality by the sanitary improvements enumerated in Dr. Buchanan's report. In fifteen towns out of the twenty-five examined the phthisis death-rate exhibited a reduction varying from 49 to 11 per cent. This reduction can only be attributed to the drying of the subsoil which accompanied the laying of the main sewers in the improved towns. Where the drying of the subsoil was greatest, and where it was most needed, as in Salisbury, Ely, Rugby, and Banbury, there the deaths from consumption showed the greatest reduction. In the towns, on the other hand, where the drying of the subsoil was inconsiderable, or had not taken place at all, phthisis was found to be stationary or had even increased. In some cases this was due to the fact that the soil already contained little water, and so did not require draining, whilst in others the soil required draining, but no subsoil drainage had accompanied the laying of impervious pipe sewers, superficial culverts for storm waters only being thought necessary.

OFFENSIVE AND NOXIOUS BUSINESSES

BY

THOS. WHITESIDE HIME, B.A., M.D.

OFFENSIVE BUSINESSES

THE businesses which may come under the notice of the Health Officer as giving rise to nuisance, or proving injurious to the health of the community, are innumerable; and they can only be classified with difficulty. They may, perhaps, be best dealt with under the heads of (A) businesses dealing with animal and vegetable matters; and (B) those in which known gases or vapours of mineral substances are evolved.

A. BUSINESSES DEALING WITH ANIMAL AND VEGETABLE MATTERS

These can scarcely be further classified, and will be described *seriatim*.

The slaughtering of animals for food is a business to which a separate article is devoted (q.v.)

SLAUGHTERING OF ANIMALS

The following is the mode of disposal of the most important parts, commonly regarded as 'offal:'—

1. The *blood* of pigs and sheep is either used for making 'black puddings,' mixed with fat and condiments; or it is used for pig's-food; or it is used for making albumen (for which purpose the blood is received in shallow pans, allowed to coagulate, and the clot being removed for manure the serum is condensed and coagulated for albumen); or the fibrin having been removed the remainder is sent to the turkey red dyer (*vide* TURKEY RED).

2. *The Viscera.*—The first stomach (paunch, tripes) of cattle and sheep is cut open, emptied and cleaned for human food. The second stomach is usually used as food for dogs or pigs. The heart is used as food for man; the lungs and liver are used so occasionally, but are more commonly given to animals. The small intestines (running gut) are either sent to the gut-scraper, after all the fat has been cut off them, or they are used for food for animals, or thrown on the dung-heap. The small intestines of pigs are used as sausage-skins, or go to the gut-scraper; the large intestines are used as human food.

The fat of pigs is usually rendered into lard by the pig-killer himself.

The fat of cattle and sheep is commonly removed soon to the fat-melter.

The hides of cattle go to the tanner; their feet to the tripe-boiler, and sheep-skins to the fellmonger.

POULTRY

The keeping of poultry in large towns is often a great nuisance, especially as it is generally in the very poorest localities, where air and space are so scarce, that people will insist on keeping them. Poor people will keep fowls in the cellars of their houses, or in the very small yards attached to them,

and endure continuous hostility from their neighbours, rather than give them up. There is no way of abating this nuisance, as a rule, except by abolishing it. Poultry are almost invariably brought dead to the food market or poultry dealer's; and it would be a great advantage if it were customary to have them plucked also before they are brought from the country.

Knackeries; Horse-slaughtering

The knacker (originally knacker = saddler, who killed the animal and utilised the skin) is a most useful public servant, not always held in such estimation as he deserves. He properly is a horse-slaughterer, but he also slaughters old and diseased animals other than horses, and commonly receives carcases of animals which have died of disease or violence as well. The slaughtering of horses for food for man in such places should not be tolerated. There is no reason why such animals should not very commonly be killed where they are kept, instead of being conveyed alive, and at much greater trouble, to the place of slaughter.

These places can be and should be conducted so as to be no more nuisance than is a slaughter-house for cattle. Frequently they are managed in a very offensive manner. In large towns they are often situated in poor, populous districts, sometimes in the suburbs.

The principal sources of nuisance arise, not from the slaughtering, but from subsidiary trades—bone-boiling, flesh-boiling (for cat's-meat or fat-extraction), manure-making, &c.—which are commonly carried on at knackeries to utilise the materials.

Where there is a large business many live animals may be received daily, and may have to be kept for some days, necessitating the provision of food and shelter for them.

The horse is slaughtered in the same manner as an ox (by the poleaxe or the head-strap and spike), and afterwards all the soft parts are stripped from the skeleton, which, in turn, is broken up and utilised for boiling (fat, size, &c.), like all the rest of the carcase, except the feet and the long hair of the tail.

Knackeries may become offensive owing to the filthy way in which the live animals are kept before slaughter, or owing to putrid carcases or other material being allowed to remain on the premises; or owing to the steam from the boiling of bones and meat, or in consequence of the hot boiled material being left lying about to cool, and giving off offensive vapour; when putrid stuff has been boiled this nuisance is greatly increased. Complaints are also sometimes made of very offensive smells from the public drains, owing to the liquor, especially if it is hot, being discharged into them. But the discharge of liquids at over 80° F. temperature is now prohibited by statute.

The general principles for preventing nuisance arising from knackeries are precisely the same as those laid down for the construction and management of slaughter-houses for cattle (q.v.), the cardinal point being the observance of strict cleanliness. The premises must be conveniently situated, well lighted, ventilated, drained, and surrounded by a wall to conceal from the view of the neighbours all the operations going on inside. The floors should be impervious, smooth, properly guttered, and sloped towards the drains. The bottom 5–6 feet of the wall should be coated with glazed tiles or bricks, concrete, or other impervious material, which can be thoroughly washed with a hose and brush. The less woodwork there is the better; and wherever possible iron should be substituted for it.

Proper receptacles, with well-fitting lids, should be provided for convey-

ing all garbage from, and as far as possible for conveying offensive stuff to the works. Much annoyance would be avoided by the use of a suitable covered waggon and the application of deodorants. Knackers seem to pride themselves on the light, skeleton-like character of their carts, which should, on the contrary, be closed and substantially made. There should be no dung-heap on the premises; all such stuff should be removed daily in proper vessels. If there are more carcases brought in than can be dealt with in the ordinary way, they should be buried or destroyed, and must not be left lying putrefying about the place. Carcases exposed to the action of steam under pressure in a receptacle are soon reduced to a pulp, the bones being blanched, and ready for the superphosphate maker. The pulp will soon solidify and be ready for manure-making. Or such carcases might be treated with oil of vitriol; if well covered with dry earth, ashes, charcoal, or other deodorant, they might be kept for days without nuisance if under a shed. Carcases should not be allowed to lie exposed to the weather, but should be kept under cover in a well-aërated shed. The nuisance from the steam must be dealt with by having a properly fitting hood to the boiler, and conducting the vapours under and into the fire, or by condensing them in a cold shower-bath; the liquor should not be run into the drains until it is cold. All annoyance from the steaming meat will be stopped by placing it in cold water directly it is taken from the boiler.

Boiling of Tripe, Ox-feet, Trotters, Flesh, &c.

The preparation of these materials as articles of human food involves in many cases annoyance to the neighbourhood, in consequence of want of reasonable care and proper appliances, and hence it calls for the supervision of the Sanitary Authority.

Tripe is the first stomach (paunch) of the ox or sheep. It is usually emptied of its contents at the slaughter-house, is subsequently washed and scalded, and the villous membrane is then scraped off with a knife or revolving brush. The tripe is then boiled, commonly in a boiler set in brickwork, but better in a pan with a steam-jacket. When cooked it is hung up to drain and cool, and the liquor is run off into the drains. The fat is collected for soap-making. Sometimes the boiling of trotters and ox-feet is done in conjunction with that of tripe.

Ox-feet ('cowheels'), if intended for food, are first roughly dressed, any adherent skin being removed (and set aside for glue-making where economy is practised), and boiled, the fat being collected from the surface and used as an inferior 'neat's foot oil.' Sheep's trotters, after being scalded, have the hoofs taken off, and after removal of hair, loose skin, &c., are fit for boiling.

If not intended for food, the ox-feet go through a careful series of operations, so as to utilise every part as far as possible. In small works there is great waste, and many of the operations here referred to are entirely neglected and the materials allowed to go to waste. But where proper appliances and skill are available the treatment is briefly as follows:—

The skins having been stripped off are treated with lime-water to form glue-pieces (*vide* Glue). The hoof is then slit up between its divisions and the ends of the two long bones are divided. The collection of soft fat near the hoof is carefully removed, being the source of the best 'neat's foot oil.' The hoof is then cut off, washed, and boiled, usually in pans on an open fire. After boiling for some three hours the hoofs are removed, and set aside for the comb- and button-maker, &c., the oil which has been boiled out being kept as an inferior 'neat's foot oil.' The smaller bones are utilised

for manure, the larger shank-bones for knife-handles, and the liquor is either further utilised for whatever oil it contains or run into the drains.

Sheep's trotters which are too putrid to be used for food are limed, and then similarly boiled, the fat being skimmed off and sent to the soap-maker, and the residue (except the skin, which is used for glue) is variously disposed of, the larger bones to the bone manufacturer, the smaller, together with hair, flesh, &c., to the manure-maker. As only trotters which are in an offensive state are used for this purpose, there is often a most unpleasant odour produced throughout the place where the operation is carried on.

Boiling of Flesh from Horses and other Carcases

In most knackers' yards there exist arrangements, sometimes of a very primitive kind, for boiling the flesh of horses and other animals which, from some cause, is unfit for human food, and utilising it to make cat's-meat, to produce grease, &c.

Carcases have to be disposed of in considerable numbers in all large towns, and considering that many of them are in a very offensive state when they arrive at the knackeries, it is not surprising that the boiling of them is sometimes most offensive. The worse the raw material, the worse the nuisance.

But the knacker's yard is a necessary and most useful institution, and it need not necessarily be a nuisance.

The nuisances emanating from such places arise usually from some or several of the following causes :—

(1) General filthy condition of the premises, owing to unsuitability for the work, and want of care in carrying it on.

(2) The accumulation of material on the premises, carcases waiting to be treated, scraped bones waiting to be boiled, and bones lying in heaps after boiling ; hoofs and horns, blood, scraps of skin, fat, hair, &c.

(3) The seething materials just removed from the boiler being thrown on the ground and emitting stinking fumes while they cool.

(4) The fumes from the boiler in action, or while being emptied.

With regard to (1) it is absolutely necessary, if such premises are to exist near inhabited localities, that they must be suitably constructed, and that the business should be carried on with care. The business is generally profitable, and all the nuisances complained of are associated with waste and loss of money. So that in insisting on the substitution, e.g. of proper steam-jacketed boilers for open pans for boiling bones on the fire, one may have the assurance, in spite of protests, that the business will not be ruined, but that far more work will be done at a cheaper rate, in a better manner and in a shorter time, and withal in such a way as to minimise or abate what was a horrible nuisance.

The premises must not be too close to inhabited houses, and yet they must be in an easily accessible situation, so that there may be no difficulty in getting carcases conveyed there. They should be large enough for the amount of work to be done, and the buildings should be suitable. Little is required in the way of buildings—there must be a good boundary wall, and there should be sufficient covered space to prevent the necessity of material being left lying in the open, exposed to the weather. The floor should be smooth, paved with some suitable material, and it should be well channelled and drained. The walls should be covered with a smooth coat of concrete, or plaster, or glazed brick, at the lower part where there is liability of their being splashed with filth. A tall chimney is required with a good draught, and the boilers should be so constructed with hopper-lids or other appliance that vapour from them will be

drawn up the chimney. Where there is much boiling done, and there is a liability to cause a nuisance to neighbouring houses, there should be steam-jacketed boilers, or means for applying free steam with a water-jointed lid, and means for conducting the vapour downwards under and into the fire, so as to burn it before it reaches the chimney.

(2) Nuisance under this head will need proper covered sheds, with good floors; air-tight buckets for packing waste which is to be removed; and above all a sufficient staff of workers to prevent excessive accumulation of work.

(3) There must either be means for rapidly cooling the meat (cold water, cool cellaring, &c.), or else properly closed sheds communicating with the chimney by means of a good air-shaft, whereby the vapour may be conducted away; the air-shaft if needful to be provided with a gas jet, or fan, or other means of strengthening the draught when the chimney is not heated.

(4) There is no difficulty in obviating this nuisance, and at very small expense. There are various arrangements suitable for the purpose, whereby the vapours are either conducted under the fire-place and burned, or passed into a tank of cold water and condensed (the residual gases being if necessary conducted under the fire and burned), or conducted into a scrubber or into some form of shower bath, where rapid cooling and condensation may be effected.

Gut-cleaning

The small intestines of pigs[1] and sheep (termed 'rops' in the North of England) are used for sausage making and for making catgut. The muscular and mucous layers are not required for these purposes, and their removal is the work of the gut-scraper or cleaner, who leaves only the peritoneal covering for the purposes indicated above. The guts are first cleaned and the contents evacuated in water by a man, or water is run through them from the tap, after which they are left lying in salt and cold water for six to eight days or longer in cold weather, and afterwards for four to five days in plain cold water until the tissues have been so softened that their separation is easy. To effect this the guts are removed from the tank and placed on a table, and the gut is rubbed with the back of a knife or a piece of wood, being passed along from hand to hand. It is then thrown again into water.

If required for sausage skins, the gut is then simply placed in salt. Catgut is made out of the guts thus prepared (without being salted) by sewing the ends together with a needle and thread, and spinning them by an ordinary spinning-wheel. The thickness of the cat-gut depends on the number of strands of gut in it. The strings are usually bleached by exposure for two to three days to the fumes of burning sulphur in a special chamber, after which they are dried by being stretched over pegs in the open air, but protected from rain and sun.

The guts are prepared for spinning by being steeped in a weak solution of carbonate of sodium, which is changed twice a day during seven to eight days; and at each change they are run through a hole formed at the angle of a piece of bent copper-plate.

Places where gut-spinning is carried on are, as a rule, kept in an exceedingly offensive condition. 'Rop'-cleaning, or the preparation of sausage skins, is also sometimes, but not so often, a nuisance.

In the latter case the nuisance is usually due to scraps allowed to accu-

[1] The intestines of the pig average 72 feet in length, of which 56 go to the small, and 16 to the large intestine. The intestines of the ox measure about 147 feet in length.

mulate and putrefy on the premises, in order to have enough to make a load to send away. The water in which the guts are kept is also, at times, very offensive.

The prevention of such nuisances is easy enough: the premises should be adapted to the work, and be provided with proper stone tables and other appliances; the storage of material for any length of time should be forbidden, and what material is there should be kept in properly covered and non-absorbent receptacles. The liquor should be deodorised with chloralum or chlorinated soda, which may be used even when the guts are in steep, and which obviates putrid fermentation. The disintegration of the tissues might be accelerated by warming the water to from 80° to 89° F.

The annoyance from this business is often mainly due to its being carried on in places never intended for such work. A man will commence sausage-making in a small way in a private house, perhaps one of a row of workmen's dwellings, without any yard or accommodation. He feeds a pig somewhere, gets it killed and conveys the guts to his house to prepare the sausage-skins, either in the dwelling-house, or in an improvised place in the yard, which is probably hardly large enough for the ordinary purposes of a dwelling-house. What wonder if the neighbours complain in such a case as this! It should be forbidden by law to carry on work of this kind except on duly authorised premises.

The cat-gut making is almost invariably carried on so as to be a nuisance, the most horrible stench pervading the place and attaching itself to the person and clothes of everyone who remains in it even a short time, and spreading to a considerable distance around the premises, which themselves become saturated with stench.

Still, there are many who will maintain that health is not injured by the nuisance. It is no doubt possible for persons to become acclimatised to such an atmosphere, but for the average man it cannot be regarded as healthy, and sanitary regulations must be framed with a view to the average man.

The building must be adapted to the trade, and be properly situated, at a convenient distance from dwelling-houses. The more offensive work should be carried on in a closed chamber, with active artificial ventilation, and an arrangement for driving the foul air through the fire, so as to burn it before it escapes into the atmosphere. The floors should be constructed of concrete or flags, or other suitable material, and properly sloped to the drain, and the walls should be also concreted or plastered or otherwise rendered impervious to a height of five to six feet. There should be an abundant supply of water, and a hose kept for swilling the place.

But nothing will prevent a nuisance unless care be continually exercised to keep the place clean, and never to allow filth to accumulate. The cleansing of it must be frequent and thorough.

No accumulations of stinking material should be tolerated on the premises, and there should be proper vessels for conveying material to and from the place.

Utilisation of Blood

Manufacture of Blood Albumen

The albumen is prepared by desiccating the serum, from which the clot has been separated. For the purpose of this trade the blood must be fresh; hence there is no offensiveness essentially connected with it.

The serum contained in the clots is drained off by slicing the clots, which are placed on a strainer above a pan, so situated as to catch the serum

as it oozes from the contracting clots, a process which lasts from twelve to twenty-four hours, according as the weather is hot or cold. When a high-class albumen, free from colour, is required, this reddish serum is transferred to a cask and allowed to stand until the red colouring matter has subsided. Inferior, coloured albumen is prepared by drying the albumen without waiting for it to settle. The drying is effected in shallow iron pans placed in a room heated to about 120° F. The clot is commonly used for manure-making.

This trade is now commonly carried on in connection with large public abattoirs, and where there are space and cleanliness there is no nuisance. But if the premises be small and in a crowded district, and if reasonable care be not exercised, and especially if blood from other sources besides that from animals slaughtered on the premises be collected and be utilised for manure-making, there may be complaints of a nuisance. The complaints are usually owing to old material (clots, &c.) retained on the premises until it is putrid, and from a general unpleasant smell which pervades the place, if not kept perfectly clean.

When not directly used for manure-making, &c., on the premises, the clot should be put in proper air-tight receptacles, and removed as soon as possible. It should never be allowed to accumulate in the yard, and there should be no dung-heap on which to throw it, except what may be collected from day to day.

The premises should be kept scrupulously clean, especially the floors, which should be of impervious material, as they are liable to be splashed with blood. It is difficult to keep the divisions between flag-stones thoroughly water-tight; hence concrete is better. The yard, too, should be well paved and drained. The clot-room and the drying-room should be effectually closed on all sides, and be lighted and ventilated from the roof. The most effective way would be to draw off all the air by a fan into the furnace, through which it would pass into a tall chimney. All the implements and appliances used in the business must be kept thoroughly clean.

Blood Manure

Blood-clot is sometimes utilised by being mixed with an acid, usually brown sulphuric acid (rarely hydrochloric acid), desiccated, pulverised, and mixed with other materials such as superphosphate, scutch manures, &c. The blood is thoroughly mixed with the acid, and stirred until the whole is reduced to the consistence of porridge. It is then dug out and allowed to dry in the air, which takes three to four days in summer, and rather longer in winter. It must of course be protected from the rain. Sometimes it is dried by artificial heat on a floor heated by steam, which is much more likely to cause nuisance. While it is drying a certain amount of red acid liquid drains off, which may be utilised in the succeeding operations.

Apart from nuisance arising from filth allowed to accumulate on the premises, there is little to complain of in this business, except during the mixing of the blood and acid, when very offensive vapours are given off, and during drying by artificial heat. The former operation should be conducted in a covered chamber, the vapour from which should be conducted under and into the fire, or into water. The drying should always be effected either spontaneously in the air, or by steam, and never by direct fire-heat, as it is difficult to avoid a horrible stench from overheating the parts next the fire.

Blood-boiling and Drying

The clot from albumen works, and blood which has become too putrid for making albumen is sometimes desiccated on a floor heated artificially, or in a boiler by direct fire-heat. The latter method is almost certain to cause a nuisance, by over-heating the blood. Whichever process is used, the vapour should be conducted by a hood and flue, under and into the fire, before being discharged into the air. Or in some cases it may even be necessary to pass it first through a cold-water condenser, to absorb part of the vapours and gases.

Preparation of Blood for Turkey-red Dyeing

Before the introduction of alizarin, cotton dyers used madder, and its commercial preparation garancine, to produce the red colour known as turkey red, remarkable for its brilliancy and fastness both to light and boiling alkaline solutions.

Alizarin, formerly only known as a substance obtainable from madder root, is now made in large quantities from the coal-tar product, anthracene, and has almost entirely displaced madder, as the colours it produces are far more brilliant, quite as fast, and less expensive. Bullock's blood is used to fix the alizarin on the cotton, by the coagulation of its albumen.

The blood is prepared first by collecting the serum which has already separated from the clot, residual serum being extracted from the clot itself by placing it on a strainer above the vessel and slicing it, and subsequently treating the clot with water, which is allowed to run into the reservoir with the serum. The clot itself is then rubbed up with water, and strained into the remainder of the liquor, and the whole is then put in barrels for use.

As the blood is usually more or less putrid during the whole of these operations, a horrible stench is produced, which may be perceived a long way from the works.

The nuisance may be obviated by conducting the operation in a closed chamber provided with a suitable flue to carry off the vapours from the place where the work is carried on, and the use of a fan to convey them under and into a fire, connected with a high chimney.

It is at the same time essential that scrupulous cleanliness be observed on the premises, that the floor be constantly cleansed from all blood which has fallen on it, and that all the utensils be kept sweet. The place where the work is carried on must be well closed in, and not exposed to the action of the wind, or else the ventilating fan cannot act effectively.

The following is an abstract of the bye-laws framed by the London County Council, under the Slaughterhouses &c. (Metropolis) Act, 1874, for the regulation of the business of a blood drier, and any business in which blood, or any constituent parts of blood, is used, provided that heat be in any way applied or used to the same:—

1. Every blood drier shall cause all blood brought upon his premises to be brought in closed vessels or receptacles constructed of galvanised iron or other non-absorbent material.

2. Every blood drier shall cause every process of his business (except the drying and packing processes to be carried on in a building properly paved with asphalte, concrete, or other suitable jointless material, having walls covered to the height of at least six feet, with hard, smooth, and impervious material.

3. Every blood drier shall cause every process of his business in which any offensive

effluvia, vapours, or gases are generated, to be carried on in such manner that no offensive effluvia, vapours, or gases shall escape into the external atmosphere; and he shall cause all such offensive effluvia, vapours, or gases to be effectually destroyed.

4. Every blood drier shall cause all blood, blood-clot, or any refuse, residue, or other matter from which offensive effluvia or vapours are evolved, or are liable to be evolved, to be placed in properly closed receptacles, or to be otherwise dealt with in such manner as to prevent any offensive effluvia or vapours therefrom escaping into the external atmosphere.

5. Every blood drier shall cause the floor of every place in which any process of the business (except the drying and packing processes) is carried on to be thoroughly cleansed with water at least once in twenty-four hours; and he shall cause the premises to be constantly provided with an adequate supply of water for the purpose.

6 Provides for the periodical cleansing of the premises, and 7 provides for the due and frequent cleansing of the vessels used.

11. Every blood drier shall cause the floor of the yard and every part of his premises in which any process of his business (except the drying and packing processes) is carried on, to be properly paved with asphalte, concrete, or other suitable jointless material, laid upon a suitable bottom of at least four inches in thickness, and such floor to have a proper slope towards a channel or gulley; and shall cause his premises to be effectually drained by adequate drains communicating with a public sewer. The drains shall be properly trapped, and the entrances thereto shall be covered with fixed gratings, the bars of which shall not be more than three-eighths of an inch apart.

13. Every blood drier shall cause his premises to be provided with appliances capable of effectually destroying all offensive effluvia, vapours, or gases arising in any process of his business, or from any material, residue, or other substance which may be kept or stored upon his premises.

FISH-FRYING

The frying of fish for sale, ready-cooked, is a business that gives rise to many complaints. The trade exists almost entirely for the poorer class, and hence the shops are usually, but by no means invariably, situated in poor thickly populated streets. The complaints do not generally come from the poor for whom the trade is carried on, but from persons living at a little distance, whom the effluvia from the chimney may reach, or from persons who are in the habit of frequently passing the premises.

The smell is often very unpleasant. The nuisance is sometimes intensified by the continued use for a considerable time (many weeks) of oil in which fish is constantly being cooked.

The cooking commonly consists in ordinary frying, when the oil is in a constant state of effervescence [the oil itself being rarely boiled; it is the water in it which is raised to boiling point, and causes the phenomenon commonly, but erroneously, called 'boiling].' Particles of the oil escape, with bubbles of water escaping from it, and spread the smell, and as the oil, as well as part of the fish are usually partially burned from the cooking on the open fire, strong empyreumatic odours are produced.

If oil at a high temperature were used, as is so common in France, to cook the food at a high temperature (without the food itself being browned or burned by actual contact with the hot pan), the cooking would be much more effective, and it would make the food much more palatable, and at the same time the burning which causes much of the nuisance would be avoided.

The fact that the cooking is usually carried on on the open fire, in the open shop, and subject to draughts of wind, causes the effluvia to be blown about in all directions.

The use of a deep vessel of oil (six to ten inches of oil according to requirements), kept at a high temperature, in which the fish could be cooked without burning, and the addition of a hopper above to carry off the effluvium into a high chimney, will generally put a stop to all nuisance. A good gas

burner may be required to increase the draught up the pipe from the hopper. The chimney must be high enough to conduct the vapours above neighbouring houses. If further steps are required, the vapours may be conducted under the fire, and obliged to pass through it, which will lead to their combustion, or they may be conducted through water. After washing the vapour there seldom remains any offensive smell.

The cooking vessel should also be provided with a well-fitting lid, which can be easily raised and lowered, and provided with a suitable opening to enable the cook to inspect the interior at will.

GLUE

This important article is made from almost every kind of waste animal tissue; it is chiefly obtained from bones (after the fat has been extracted by boiling), hoofs, horns, scraps cut off during the preparation of skins for leather, scraps of leather, parchment, &c. The raw material which has not already been limed (leather is differently treated) is first limed, and then washed, boiled, and stirred for some hours in a vessel with a false perforated bottom (to keep the material from burning at the bottom). The thick fluid is drawn off after it has cooled, and is allowed to settle into a second receptacle, where it continues to stand and further clear. The use of superheated steam is a great improvement on this method, giving a better return in a shorter time. After a time the liquor is drawn off into wooden boxes, about 14 ft. × 12 in. × 9 in. deep, in which it cools in the course of twelve to eighteen hours. The glue is then removed from the boxes, placed in wooden frames and cut into slices to dry, during which latter process it shrinks to about half its bulk.

When scrap leather is used it is treated with slaked lime and water at a high temperature (about 250° F.) By this means the leather is decomposed, the tannin combines with lime, and the gelatine becomes dissolved in the water. Glue made in this way is of inferior quality.

Glue which has become foul during preparation has the curious and unpleasant property of recovering its evil odour long afterwards, when in use on walls, wood, &c., if it becomes moist. Size is made in the same way as glue, only from better material and with more care; it may be cheap and little superior to glue in quality, or of very superior quality, such as is used for making gelatine and isinglass. It is sold both in the solid and liquid form. The latter is commonly nothing but a very dilute solution of glue. But a cheaper and better article is now largely used, made from powdered resin dissolved in a warm aqueous solution of soda.

The manufacture of glue is often attended by great nuisance, though not necessarily so. The nuisance most frequently complained of is the smell from the hot pans. The character of the material used has a great deal to do with the nuisance, old foul scraps causing a penetrating, acrid odour, very different from that arising from good fresh material. Besides this effluvium, nuisance may arise from the general filth of a badly managed place, where decomposing organic matter is allowed to collect on the ground, or to adhere to the walls and the thousand places where dirt can accumulate. The *débris* from the vats, after the glue has been drawn off, commonly known as 'scutch,' is a fruitful source of nuisance when allowed to accumulate. The sooner it is barrelled and removed the better. Should delay unavoidably occur in doing this, the scutch will be best kept in a dry, airy place; for it is very likely to putrefy and become offensive if kept exposed to the

vicissitudes of our climate. Carbolic powder sprinkled over it is a useful protective.

There is often much nuisance produced by accumulations of raw material on the premises before use. This may, without injury, and with the best prospect of avoidance of nuisance, be stacked, each layer of a few inches thick being well covered with milk of lime. This material must not be exposed to damp, otherwise putrefaction and stench (as well as destruction of valuable material) must certainly ensue.

The stench from the boiling process is always worst where open fires are used; hence heating by steam is to be recommended as a preventive, and as probably a more economical method. The vapour may be conducted under and into the fire, and burned, or into a scrubber, where it would be washed and condensed. It should always be at last conducted into a tall chimney.

The after-treatment of the 'scutch,' to remove the fat from it, deserves notice. It is usually treated with hot water, or cold water with steam, and the fat skimmed off, the residue being pressed in coarse canvas to extract the last remnants of grease. The cake is used for manure. If kept dry and under cover, it will keep inoffensive for some time; but if allowed to accumulate in the open air, it soon becomes offensive.

RECOVERING GREASE FROM SOAP SUDS[1]

In districts where the manufacture of wool is carried on there is often annoyance caused by the warm suds produced in washing the wool, some kinds of which are very greasy; as well as by the efforts to utilise the wool-fat ('suint') and the large quantities of soap which are employed in the washing.

This was at one time a large and profitable business, but for some years past has declined. In many large wool works the grease is recovered and converted into soap on the premises, and one lot of wool is actually washed with soap extracted as an impurity out of a preceding lot.

But some persons make a special business of recovering the grease, and for this purpose collect the suds from several wool-washing places. The liquid is roughly strained as it passes into a large tank (which is sometimes heated by steam), when sulphuric acid is added, and mixed with it in sufficient excess to slightly acidify the liquor. The acid combines with the soda, potash, and other alkalies present in the soap and wool-fat, and the grease being set free rises to the top as a dirty scum known as 'magma.' The liquor is then run off from the bottom, usually direct into the drain, and the magma is either collected directly on coarse canvas, through which it drains, or it is removed and allowed to drain in a hole in the ground in the open air. Afterwards, and while still wrapped in the canvas (called 'bags'), it is put in a press and is squeezed while heated by steam. The grease and some water and dirt escape from the bottom into a tank, where the grease again separates and floats, and is ladled out into a vessel, in which it is again treated with sulphuric acid to remove the water, after which it is put in barrels for sale either to be further purified or to be used for common work. The residue in the 'bags' is commonly used as manure, or thrown away. Sometimes it is further treated with bisulphide of carbon, and a profitable business may be done in recovering the residue fat by this interesting process. The cake to be treated is first ground in a mortar-mill and then placed in a cylinder containing the bisulphide, which dissolves

[1] Cf. Article on Manufacture of Soap, p. 912.

every trace of fat. Steam is then let into the cylinder and separates the two, the fat being run off by one tap and the bisulphide retained to be used over again. There is but small loss of bisulphide at each operation, and this is made good by the necessary addition of more, and the process is kept in constant operation.

This process is exceedingly dangerous, owing to the inflammable nature of the bisulphide. No light must be burned inside the building where it is used. The plan adopted is to have the chamber where the operation is carried out carefully boarded off, the partition having windows in it, outside of which are placed the gas-lights. This bisulphide process is carried on at Frizinghall, a suburb of Bradford, Yorks., without the slightest nuisance.

The nuisance complained of in treating the suds is from offensive smells, due to putrefaction from over-keeping. This can only be prevented by the avoidance of this unnecessary practice. The warming of the suds by steam accelerates the work, and the adoption of this plan would undoubtedly assist in getting rid of objectionable material more rapidly and preventing nuisance. The press is also liable to cause offensive smells, but only to a slight extent, and chiefly in hot weather. The discharge of the acid liquor into the sewer is alleged, but hardly on sufficient grounds, to greatly increase the evolution of offensive gases (sulphuretted hydrogen) from the sewers. When the liquor smells offensively, it may be deodorised by the addition of proto-sulphate of iron (about 20 lb. of the salt to 1,000 gallons of the liquor).

DIP-CANDLE-MAKING. FAT-MELTING

These associated processes are still carried on in almost all large towns, notwithstanding the general use of gas, illuminating oils for lamps, and the immense trade in candles from wholesale manufacturers, which the great cheapness of traffic allows to be retailed in the smallest village at a moderate price.

Fat-melting is required for the purpose of making soap, waggon-grease, candles, and other purposes. The materials used are chiefly beef, mutton, and pig fat, kitchen-waste, dripping, fat collected from plates and dishes, and waste meat; also the scraps of meat, fat, &c., collected by itinerant rag-and-bone men, and not infrequently inferior stuff obtained from the boiling down of bones and scraps at knacker-yards, tripe- and glue-boiling works, &c.

Tallow is either mutton or beef fat, or a mixture of both, usually prepared by heating crude fat in contact with water or steam until the membranous covering in which the fatty matter is encased swells and bursts; after the whole has cooled, the membranous covering is found between the water and the superjacent tallow. Lard is pig's fat similarly freed from its membranous covering. 'Moulds,' i.e. candles shaped in moulds, are made of mutton suet. 'Dips,' or inferior candles, are made by dipping a wick into the molten fat, made from inferior tallow, and repeating the process until the candle is sufficiently thick.

Chevreuil, who carefully investigated the subject of the chemistry of fats, has shown that the ordinary commercial neutral fats are to be regarded as chemical 'salts,' in which glycerine forms the base in combination with one of various fatty acids. When a neutral fat is boiled or 'rendered,' in the ordinary way along with soda, lime, or other strong alkali, the latter displaces the glycerine and combines with the fatty acids, forming a soap.

When, as happens in certain processes, the soap is 'broken' by the

addition of a strong mineral acid, e.g. sulphuric, the latter combines with the alkali, and the fatty acids are set free.

The usual mode of melting fats, derived from the various sources mentioned above, is simple in the extreme: the fat is placed in a pan, usually set in brickwork over an open fire, and is stirred from time to time.

When 'raw' fat direct from the carcase has to be melted it is usual to chop it up to facilitate the melting, and thus in some degree to obviate the danger of burning it; but when it is treated with sulphuric acid and steam it is rarely chopped. When steam is used direct, it is conducted by a pipe down to the bottom of the boiler filled with fat.

The melted tallow is either run off through a tap, or ladled out by hand into a vessel in which it is allowed to settle; it is advantageous, but exceptional, to ladle it through a strainer.

The residue, after all the tallow has been removed, consisting of scraps of membranes of various kinds, sinew, skin, &c., is with advantage squeezed through a press to extract all remnants of fat, and the remaining solids, known as 'greaves,' are commonly used for manure, or, if of better kind, as food for animals.

Apparatus of various kinds has been devised for the rendering of lard to make the process more expeditious and economical. In some methods these objects have been successfully combined with the suppression of nuisance.

The great secret in preventing nuisance is the avoidance of burning the materials, or even raising them to a high temperature. The lower the temperature at which the work can be successfully carried on, the less is the risk of the production of offensive smells. The temperature need not exceed about 120° F. It is in summer weather that nuisance is most complained of; the time when most people are liable to feel easily annoyed by even the smells of ordinary domestic cooking. 'Heavy' damp weather, too, is likely to make the smells hang about the neighbourhood and cause offence.

The fresher and sweeter the materials used, the less is the danger of nuisance during the melting. A little care in keeping the fresh materials would often prevent loss and nuisance; a cool, well-aërated room is the best place to keep it till wanted. The general principles of preventing nuisance from this trade are the same as those mentioned in the sections on tripe-boiling, &c. The nuisance arising from the pressing of the 'greaves' is sometimes rather troublesome to overcome, but by conducting the operation under cover, the whole apparatus being, if necessary, boxed in, and by operating in a closed room where there is a good draught into the chimney, all nuisance may be completely suppressed.

Unless fat-melters will adopt proper precautions, they should be obliged to remove from populous districts.

General cleanliness, the use of good material, melting at a low temperature, and the use of steam and acid are the cardinal points to be attended to with a view to conducting this business without nuisance.

The following are extracts from the bye-laws in force for the regulation of these businesses in the metropolis :—

1. Every fat melter or fat extractor shall cause every process of his business in which any offensive effluvia, vapours, or gases are generated to be carried on in such manner that all offensive effluvia, vapours, or gases shall be effectually destroyed.

2. Every fat melter or fat extractor shall cause all material used or offensive material or refuse from the boiling pans, and all refuse, residue, or other matters from which offensive effluvia, vapours, or gases are evolved, or are liable to be evolved, to be placed in properly closed receptacles, or to be otherwise dealt with in such manner as to prevent any offensive effluvia, vapours, or gases therefrom escaping into the external atmosphere.

3. Every fat melter or fat extractor shall cause all scraps or litter composed of matters liable to become decomposed to be constantly gathered or swept up and placed in properly covered receptacles.

4. Every fat melter or fat extractor shall cause the floor of every place in which any process of the business is carried on to be kept thoroughly cleansed, and he shall cause the premises to be constantly provided with an adequate supply of water for the purpose.

5 Orders the proper and periodical cleansing of the premises, and 6 the due cleansing of the premises.

10. Every fat melter or fat extractor shall cause every floor upon which any process of his business is carried on, in any part of his premises, to be properly covered with a layer of concrete, or other suitable jointless impervious material, laid (in the case of a ground floor) upon a suitable bottom of at least four inches in thickness. He shall cause every such floor to have a proper slope towards a channel or gulley, and shall cause every part of his premises wherein any such floor may be constructed to be effectually drained by adequate drains communicating with a public sewer. He shall also cause every drain to be properly trapped, and the entrance thereto to be covered with a fixed grating, the bars of which shall not be more than three-eighths of an inch apart.

11. Every fat melter or fat extractor shall cause his premises to be provided with appliances capable of effectually destroying all offensive effluvia, vapours, or gases arising in any process of his business, or from any material, residue, or other substance which may be kept or stored upon his premises.

MANUFACTURE OF SOAP[1]

This business has a sanitary interest, not so much on account of the soap itself as of the fats from which it is usually made, and the melting of which is often, though by no means necessarily, a source of nuisance.

The ordinary neutral fats must chemically be regarded as 'salts,' i.e. a combination of a base with an acid, glycerine being the base, and a fatty acid the acid. In soap-making, saponification, i.e. in the chemical actions resulting from the interaction of an alkali (soda, potash, &c.) and a neutral fat (tallow, &c.), the glycerine is displaced as the base, and its place is taken by the alkali.

Although it is theoretically true that all combinations of fatty acids with a mineral base form soaps, in practice we need only consider those which are found with soda and potash, as these, being soluble in water, are the only ones used for detergent purposes.

Soaps are divided into two classes, 'hard' and 'soft,' according to their physical characters. Soft soap almost invariably has potash as its base, and as it retains moisture, and absorbs it from the air, it is soft and pulpy, while soda soap, or 'hard' soap, dries and becomes hard in the air.

Fats of all kinds are used,[2] chiefly tallow, either pure butcher's tallow, or that collected in the treatment of skins, trotters, bone-boiling, and glue-making, also kitchen refuse, grease from wool-washing, &c. What may be termed the natural 'mottled' soap is due to decomposition of small portions of the soap owing to the unavoidable presence of negligible quantities of impurities, e.g. metallic oxides and earths. These form corresponding quantities of insoluble soaps, which are diffused throughout the general body of the material during 'boiling' and produce the mottling. Slight impurities in the fat itself cause a similar effect. Blue, grey, and red mottled soaps are modern devices to please the eye only. These soaps are silicated, i.e. made with soluble silicates of sodium and potassium; the blue mottling

[1] Cf. Article on Recovery of Grease from Suds, p. 909.

[2] Soap is also made from rosin (the kind known as colophony), which regarded chemically is an acid, which combines with the caustic alkali when added to carbonate of soda. It is, however, always used for soap in combination with fats.

is produced by admixture of artificial ultramarine, grey by finely levigated oxide of manganese.

The soap is usually made in large iron pans, set in brickwork, in which the fat, oil, or mixture of both is placed, and heated either directly by fire or, better, by free steam (i.e. discharged directly into the pan) or by pipes heated by steam. A little of the fat is first introduced, then some weak caustic lye (sp. gr. 1·05 to 1·08); the mixture is well stirred, and then more lye of a greater strength is added, and then more fat, and more lye, the boiling being continued until the materials have been introduced in proper proportions. The whole is carefully stirred, and samples are withdrawn from time to time for examination. By the addition of common salt (about 10 lb. to 100 of fatty matter) the soap is separated from the liquor in the vessel (being insoluble in strong saline solutions) and floats nearly dry and pure on the liquor. At this stage either the liquor is run off from below, or the soap is drawn off from the top. The soap is again treated with alkali and heated, and after the liquor has been run off it is placed in frames of suitable size, in which it cools and sets, after which it is cut by means of wires drawn through it into bars or blocks. It usually contains a slight excess of alkali.

Soft soap is made on the same principle as hard, potash, as already explained, being the base used instead of soda. The potash is boiled with linseed, cotton, whale, fish or other oil, alone, or mixed with other oils or some tallow (which gives a speckled appearance). A weak lye is added and well stirred with the oil, forming a viscous compound. Stronger lye is then added, and the boiling is continued, excessive foaming being prevented by breaking up the foam as it forms until the soap has attained the proper degree of viscidity and transparency. This soap contains all the 'liquor' used during its manufacture, as it is not separated by salting, as described above.

The offensiveness arising from this manufacture is practically limited to the manipulation of the fats. Some kinds of oil when heated are very unpleasant in smell, especially common kinds of fish oil. So, too, is some of the fat obtained from ships' cooking-galleys, and even kitchen stuff and butcher's fat is not always fresh, and indeed the melting of fats is generally unpleasant, unless conducted with care.

Nuisance from these causes can be obviated by conducting the melting at the lowest possible temperature, by using pans or boilers with properly fitting lids, connected by a pipe with the chimney, or, if need be, by conducting the vapours under and into the fire or into water, the lid of the pan having a door through which the boiling can be superintended. The precautions same as those required for fat-rendering.

BONE-BOILING

Bone-boiling is carried on either for the extraction of fat and gelatine, or for the ulterior utilisation of the bones themselves, or with both objects in view.

Bones from knackers' yards, butchers' shops, refuse bones collected by 'rag-and-bone men,' bones from animals which have been killed or have died, &c., are collected at the bone-boiler's, and there treated.

The 'raw' material varies from perfectly fresh to foul and stinking material, and the character of the effluvium evolved in the manufacture depends largely on the freshness or putridity of the material used. The bones are generally roughly broken up, to allow any marrow to be readily boiled out. The boiling is usually done in open iron boilers, set in brick,

and is done under cover or in the open air. The heat is applied either by open fire or by steam, and the operation is continued until it is thought all the fat is extracted, which in inferior boilers will take five to twelve hours, and then the fat is skimmed off, and the bones are commonly thrown on the ground to cool, during which cooling process very offensive effluvium is frequently given off. If size is to be extracted the boiling is prolonged for four to five days and nights. In larger works there is often a closed chamber, called a 'bone hole,' into which the bones are thrown and left till cool. If bones of a superior kind are under treatment they are generally thrown into cold water to cool, so as to preserve their colour and quality, and make them fit for making buttons, handles for knives, small spoons, &c. Superheated steam, at about 286° F., will thoroughly extract every particle of fat from a charge of bones in less than an hour; but the bones are subsequently only fit for manure.

The liquor from bones which have only been boiled for a short time, to extract the fat, is usually discharged direct into the nearest drain or stream, at a temperature which must be below 80° F.; but when the boiling has been continued with a view to size-making, the liquor is further boiled and condensed to a proper consistency, after which it is barrelled for sale.

The process is a common source of complaints arising from the offensive effluvium. The fact that the process may be continued for so long as four to five days, when size is made, is liable to make it unpleasant to neighbours, even where the smell is not what may be termed a very offensive one. But the unceasing smell of cooking, even of the finest kind, in a private kitchen finally becomes unpleasant to most persons. And at best the mawkish smell of meat-boiling without salt is not pleasant. The presence of even a little salt makes the odour much less unpleasant in ordinary meat-boiling, but it would not be possible to use it, some say, in bone-boiling. But when putrid bones are boiled, the evil is enormously aggravated, and reaches a maximum in hot or close weather.

This effluvium is to be treated like that arising during fat-boiling, &c. The importance of a sufficiently high chimney through which the vapours may be discharged is here greatly increased. The rationale of this is that vapours diffuse so rapidly in the air that they do not reach the ground in a sufficiently condensed form to prove a nuisance. For a similar reason large airy sheds are an important means of mitigating nuisance, not only by mechanically restraining the escape of the offensive vapours, but also by giving them time to be well diluted with air before they are discharged into the atmosphere. The passing of vapours under and through the fire, and the condensing them in water, will also be found available means of abating nuisance. A cheap and effective form of condensing apparatus may be made by means of ordinary drain-pipes, containing coke in lumps, kept cool and wet by water allowed to run in a small stream through it. The offensive vapours are conducted into this condenser, being forced by a fan, &c., if needful, and are found at the outlet to be almost entirely deprived of their offensive character.

The drying of the bones may be effectually done in a well-closed chamber through which a draught is maintained into the chimney; or else by artificial heat created by charcoal or coke fires; or by a short sojourn in the boiler, after the liquor has been withdrawn, the heat being maintained by the steam pipes. Of course there would have to be the same means of carrying off and dealing with the vapour from the bones drying in the boiler as with that arising from them while they were being boiled. Almost any method is preferable to the 'bone-hole' whence intolerable stench is liable to escape.

FELLMONGERING AND LEATHER-MAKING

The preparation of skins to make leather is important from a sanitary point of view. It may be effected so as to be harmless and inoffensive, if great care be exercised; or, on the other hand, it may be carried on so as to be a great and offensive nuisance, causing intolerable stench to spread to a considerable distance, and annoying those who live on either side, according to the direction of the prevailing wind.

Like every other process involving the treatment of more or less offensive materials, leather-making has found champions to declare it a panacea for all sorts of evils, and in particular it has been described as a preventive as well as a cure for phthisis!

But the mere fact that many robust, healthy men may be found engaged in the trade is no proof whatever that it is healthy; it would be quite sufficiently accounted for by the fact that the work is severe, and could only be carried on by robust, healthy workmen. Again, the statistics of Beaugrand, who found among 171 cases of disease occurring among 'leather-workers' 28 of pulmonary phthisis, are worthless as a general statement. The figures are too small, and the definition of the work too vague, to be of the least value.

Tanning, or the process of leather-making, is in its final processes a chemical preparation of the skin, and in one sense may be regarded as a kind of dyeing, when we consider the mode in which the tanning agent penetrates the skin and attacks its individual fibres. The power to precipitate solutions of albumen and gluten is characteristic of substances which can convert skins into leather. The conversion into leather prevents skins from putrefying; and altogether the process must be regarded, as described by Knapp, as being one in which the fibres do not cling together in drying.

Leather-making consists of two chief stages: (1) 'tanning' proper, or the conversion of the raw putrescible hide into an imputrescible and more or less flexible material known as leather, and (2) 'currying,' in which by treatment with fatty and other matters the leather is rendered more soft, supple, and waterproof, and improved in appearance.

Soft materials, such as glove kid, are not tanned, but 'tawed,' in which process treatment with alum and salt is the chief means employed. Sometimes skins are merely treated in a rough way by inunction with fatty matter, and are thus rendered less liable to putrefaction, though they usually retain a 'strong,' unpleasant smell.

Enamelled, patent, or *japanned* leathers are finished with a bright, varnished, waterproof surface on one side. The terms patent or japanned are generally used when the surface is smooth and bright, while 'enamelled' is the term used when the surface is grained or roughened. The artificial surface consists of coatings of a sort of paint, consisting of lampblack, Prussian blue, and linseed oil, ground together and applied in several layers, each of which is dried in an oven at about 160°–170° F. Each coat when dry is rubbed smooth with pumice-stone; and after the last one has been so treated a coat of oil varnish is applied, and afterwards dried in the oven.

Morocco leather is properly made from goat-skins. After being unhaired in the usual way the skins are bated with dog's dung and water, and are tanned chiefly with sumach. The grain or polish is given by working under rollers or boards.

Russia Leather.—The skins for making this leather are bated, after liming, with a drench of rye, oatmeal, and salt, or with dogs' dung or sour

liquors. They are again treated, after tanning, with a weak liquor of rye and oatmeal. The peculiar odour is due to saturation with birch-oil. The usual dye is Brazil wood. The markings on the leather are produced by rollers.

Calf Kid.—This leather is 'tawed' like glove kid, and not tanned like ordinary leather.

Glove kid is chiefly made from lamb and kid skin, skin of very young animals being used for the finest kid.

Preparation of Hides for Tanning.—The hides are received some fresh, and some salted, all more or less filthy. Both kinds are first well soaked in water, the salted ones for a longer time than the others.

The object is to thoroughly soften and cleanse the hide without it being allowing it to putrefy. To assist this process, brine is sometimes used; or borax, sulphide of sodium, &c., is added to the wash. Sometimes putrid liquors are used, especially for skins known as Indian 'kips.'

Unhairing the Hide.—This is almost universally done in England by the aid of lime. The lime-wash is of no very definite strength, but there is always a considerable quantity of lime in suspension. The lime-water dissolves the substance which unites the fibres of the skin together, and it also removes the albumen present in the hide (in the blood-vessels, connective tissue, &c.) The epidermal layer of the skin softens and swells in the lime bath, and the hairs are so loosened that scraping with a blunt knife causes the whole rete Malpighi and hair follicles to come away. At the same time the skin becomes swollen and plump, which renders the 'fleshing' (i.e. the removal of adherent particles of flesh) easier; the fat of the hide is also converted by the lime into an insoluble soap, and the removal of the hair is made easier.

The liming is usually done by simply plunging the skins into large pits of lime and water, out of which they are drawn ('hauled') once or twice daily, while the undissolved lime is stirred up. There is used roughly from one to four pounds of lime per hide in the pit. Instead of being simply left lying in the pit, the hides are sometimes placed on frames, which can be raised and lowered at will in the water. An addition of orpiment is very commonly made to the lime to facilitate depilation. In America and on the Continent the unhairing is frequently done by 'sweating,' which may be 'warm' or 'cold,' both processes being essentially dependent on partial putrefaction. The former was a crude method, and consisted of piling the hides and inducing slight putrefaction and heat, the hides if necessary being covered with fermenting tan.

The 'cold sweating,' or American method, consists of hanging the hides in moist 'sweating pits' at a uniform temperature of about 60°–70° F.

When the hair has been thoroughly loosened by one of these methods it is scraped off by a large two-handled knife, and scraps of fat and flesh are removed from the inner side by scraping, brushing, or paring, the hide being well worked, to press out, as far as possible, any fat in the tissues.

After being unhaired and fleshed, the hides are commonly cut up into 'bests,' or the best and thickest parts, and the 'offal,' or lighter parts. These have next to be thoroughly freed from any adherent lime before being tanned. This is done by placing them in water for from twelve to twenty-four hours.

Tanning consists in treating the hides, after liming and washing, with bark or some substance containing tannin. The chief substances used are oak-bark, one of the oldest and most popular substances, divi-divi (a South American bean, *Cisalpina coriaria*), chestnut extract (prepared from rasped

wood of the Spanish chestnut), hemlock extract (from bark of American hemlock pine), valonia (the acorn cup of an evergreen oak grown in Greece and the Levant), mimosa bark (from several kinds of Australian acacias), myrabolans or myrobalans (the fruit of an Indian shrub), catechu, kino, sumack, &c.

The ground tan is placed in pits made of flag-stone, cement, brick, &c., the pits being arranged in series according to the strength of the liquor, the skins being placed first in the weakest one and afterwards successively passed through each of the whole series.

The leather, after removal from the tan-pit, is hung on drying poles in drying lofts till half-dry, and is then placed in piles on the floor till it 'sweats' or 'heats' a little. It is subsequently scraped, oiled, and rolled to improve the texture and surface, and is often coloured. For some purposes hides are 'shaved' or cut down in thickness, or split.

Currying has for its object the preparation of soft, flexible leather, such, e.g., as is used for the uppers of boots, for flexible belting for machinery, &c. When the skins have been removed from the tan-pits they are dried, then scraped and levelled; subsequently they undergo further steeping, heating, and stretching, and are again dried. After this they are oiled. Various kinds of oil are used for oiling in the grain—whale, cod-liver, castor, linseed, &c.—while for oiling on the flesh a mixture of tallow and *dégras* is considered the best. [*Dégras* is the surplus oil which is got by exudation and pressing from the oiled chamois leather while in process of manufacture.]

From this sketch of the manufacture of leather it will be seen that it calls for the supervision of the Sanitary Authority, and may readily prove a source of serious nuisance in thickly populated districts. And yet leather-making may with proper care be carried on, and is so in many populous places, without complaint or apparent harm to the inhabitants.

But tanneries might with advantage be relegated to suburban and open districts, although if situated far from the sewers of the town nuisances may arise from the disposal of the various liquors, which are often offensive. Among the sanitary precautions called for is in the first place the prevention of the pollution of rivers by the discharge of wash-water or spent liquor. Precipitation by lime and clarification should be insisted on in all cases before such waters are allowed to run off. Where the pits are within dangerous proximity to a stream, it is advisable to have an escape tank, the bottom of which is well below the level of the river, in which the liquors can be treated. Ultimately even filtration through sand or treatment with a deodorant may be called for.

Nuisance may arise also from solid waste, hair, bits of flesh, fat, skin, &c., as well as from the *débris* from the bottom of the lime and tan-pits. The former are useful for glue-making and manure, while horns are used for comb and knife-handle making. The spent tan is also good for manure, and the liquor may with advantage in many cases be used for irrigating land.

The possibility of the presence of arsenic, especially in the case of the skins of rarer animals, which are often roughly treated with it immediately after removal from the animal in order to preserve them during carriage, must be borne in mind.

Nuisance is especially liable to arise from bits of flesh, &c., being allowed to accumulate and putrefy on the premises until a sufficient quantity has been collected to make a load for removal; such *débris* should be frequently removed and should be kept in suitable air-tight receptacles. This source of nuisance, it will be noted, is not essential to the trade, but arises from culpable neglect.

When gas lime is used instead of fresh lime, serious danger may arise from gases evolved through the action of acid liquors; sulphuretted hydrogen and carbon dioxide may be given off in fatal quantities.

The dyeing of leather has sanitary importance from the fact that in some cases dangerous metals are used for the purpose. For instance, an alkaline solution of oxide of lead is used in the preparation of astrachan, which dyes the hair black, but leaves the skin white. Such skins often contain much lead dust, which is frequently left in the hair purposely as a protection against moths. Again, the skins of foxes, otters, badgers, and rabbits, are often treated with a mixture containing protosulphate of iron, orpiment, oxide of lead, common salt, acetate of copper, and other ingredients of a highly poisonous character.

Wash-water from skins which have been treated with orpiment and lime readily gives off sulphuretted hydrogen, which leads to the production of sulphide of arsenic, and by oxidation to formation of arsenious and sulphurous acids. Free arsenious acid may also be discharged from the orpiment and form combinations with some of the calcium, which, however, are soon re-dissolved by the ammonia present whenever there is putrefaction. The danger arising from the presence of such poisons is best obviated by treatment with salts of iron, which form insoluble arseniates.

With regard to the effects of leather-making on the workmen employed, there does not seem to be any special danger or trouble to which they are liable. Some suffer from local excoriation and sores in the hands, and especially the fingers; which is no doubt mainly due to the action of the lime, though in some cases the arsenic (orpiment) used is more particularly blamed. Sometimes this ailment takes a rather characteristic form, occurring as small perforating holes in the pulp of the fingers from which blood oozes, and which are sometimes difficult to heal.

As to the use of gloves by the workmen for protection against the action of the lime, the men themselves say that the danger from lime getting inside the gloves and acting on the hands, without chance of being rubbed off, is much greater than when their hands are quite unprotected. There are no doubt some grounds for this objection; still there seems no reason why gloves to reach well up the arm should not be used. Workmen are ever ready to find reasons against any change in their *modus operandi*.

The construction of the premises where this business is carried on often leaves much to be desired. The more carefully they are adapted to the work, the less likelihood is there of a nuisance arising. It is very important that the pits should be all perfectly water-tight, that the surface of the floors around should be smooth, water-tight, properly sloped, and provided with well-laid gutters. The more open the whole of the premises are to the light and air the better. The walls should be of hard smooth material, especially the lower five to six feet, where they are liable to be splashed, so that they may not absorb dirt, and that they may be washed as often as necessary. Water for this purpose, with hose, should be at hand, as well as conveniences for the workpeople to wash themselves.

The writer once succeeded in terminating much acrimonious feeling and legal proceedings between certain persons, neighbours of leather works and the proprietors, by a simple and inexpensive plan. The works were situated in the worst possible place—the cellars and the ground floor of a large building in a very thickly populated district of a town. The building was in the centre of a long row of warehouses, all of which were occupied; and complaints of the nuisance from the tannery had been long, continuous, and well-founded. The preventive measures adopted were (1) reflooring of the

tannery with best concrete, properly sloped and guttered, and concreting of the lower five feet of the walls; (2) removal of all wood-work from the pits; stone, brick, or concrete to be used instead; (3) provision of air-tight iron boxes for scraps, and their frequent removal; (4) proper supply of water and hose; (5) provision of proper aëration of the premises by artificial means; (6) the provision of a sheet-iron flue, with large trumpet-end leading from the cellars and opening above the roof, provided with a powerful sun-gas-burner to ensure a good draught. At first there were complaints arising from the escape of effluvium from the top of the flue, which, contrary to the agreement, had been made to terminate at the roof. The addition of ten feet to the height of the flue had the satisfactory result that no further complaints were made. The workmen were as pleased with the result as the neighbours.

PIG-KEEPING

Although the Public Health Act, 1875, Sec. 47, states that pigs must not be kept in towns so as to be a nuisance, and the Public Health (London) Act, 1891, Sec. 17, prohibits in the metropolis pigs being kept so as to be a nuisance, or within forty feet of a street, still pigs are kept in towns, and even within the metropolitan area, so as to be abominable nuisances. Even in the country districts much greater care ought to be exercised in the keeping of pigs, as to site and drainage of the styes, the cleanliness of the animals, drainage, &c.

Pig-keeping becomes a nuisance (1) on account of the sour, stinking food on which they are too commonly fed, and (2) in consequence of the atrocious smell of their excreta, greatly increased by being left unremoved for long periods.

Pigs are very frequently fed on sour refuse vegetable matter, blood, offal, and other abominations, not, perhaps, as is vulgarly stated, because the animal thrives best and is healthiest when so fed, but because it is thus rendered a useful scavenger; and in one sense the pig does become a valuable member of the community by turning into useful food nutritious substances that would otherwise be wasted. There is no doubt, however, that the feeding of pigs with garbage tends to the spread of parasitic, and possibly other diseases, and it is hardly credible that the flesh of animals fed on filth is of the same quality as that of animals fed on wholesome food.

Pig-styes should be situated at a considerable distance from dwelling-houses; they should be floored with asphalte, concrete, or other hard and impervious material. Jointless floors are best. There should be a proper slope of the floor towards a channel leading to a grating, having bars not more than three-eighths of an inch apart, and communicating with the drain by a trapped inlet. The wash and other materials evolving effluvium should be kept in impervious air-tight vessels. The animals should be regularly washed and kept clean. Attention to these matters will reduce the nuisance to a minimum; and it should not be forgotten that the pig is naturally a clean animal, always depositing its excreta in a special portion of the stye, and keeping the remainder clean, if there is sufficient room.

ARTIFICIAL MANURES [1]

This subject is one of the first importance, from the magnitude of the trade and the sanitary questions involved. The trade utilises an enormous

[1] The reader desirous of learning full details on this important subject, so difficult to become acquainted with, is referred to Dr. Ballard's encyclopædic article, to which the writer is largely indebted.

amount of material which would otherwise be absolutely useless, and would be most difficult to get rid of at all; and at the same time produces a most valuable result, some small compensation for the reckless waste of the nutrition of the land which is carried on in the waste of the sewage and excrement of the population. These manures are designated as 'bone manure,' 'blood manure,' 'poudrette,' 'superphosphate,' &c.

The materials used are of various kinds and include :—

(1) What may be grouped as nitrogenous materials: the *débris* of knackers' yards, rotten flesh, fish, blood, intestines; offal from tanneries, tripe and trotter boilers', glue works, scraps of skin, hair, 'scutch,' shoddy, night-soil, &c.

(2) Phosphatic materials: bones, boiled, unboiled and calcined, animal charcoal and materials retained in it when used as a filter—e.g. sugar-scums, fossil bones, coprolites, mineral phosphates from South Carolina, Germany, and Spain, and apatite, bone black, bone ash, &c.

(3) Saline materials—e.g. sulphate of ammonia, common salt, and nitrate of soda.

(4) Deodorants and dryers—e.g. soot, gypsum, ashes from coal and burnt tar, &c.

During the process of manufacture, sulphuric acid or hydrochloric acid is used. The former acid is commonly used as 'chamber acid' (that is, acid taken and used direct from the leaden chamber where it is made), and as such almost invariably contains arsenic as a chief impurity. From two to three pounds of arsenious acid per ton of chamber acid is no uncommon quantity.

'Superphosphate' proper is prepared from a mixture of mineral phosphate and ground bones, treated with sulphuric acid. The minerals are crushed, ground, and sifted so as to reduce them to a fine powder, and are then mixed with sulphuric acid. The crushed bones are added subsequently. The mixing is done in small works by hand, but in large works, where extensive buildings and machinery are often devoted to this manufacture, it is invariably done by machinery. The mechanical mixer consists of a receiving box for the materials, and an axis or paddle with projections which revolves and stirs up the manure as it is supplied. The acid, usually 'chamber' acid, is run in from a cistern, and is stirred up with the dry material until a thick paste-like mass is produced, the consistence of which depends on the proportion of sulphate of calcium formed. This process only lasts ten to fifteen minutes, and is accompanied by strong chemical action, and the evolution of great heat and a considerable quantity of vapour. When bones alone, without mineral phosphates, are used, the heat developed has been known to reach as high as 240° F. The vapour, besides water, contains among other injurious substances fluorine (tetrafluoride of silicon), arsenic (chloride and arseniuretted hydrogen), and small quantities of antimony. The heat is useful in drying the manure, and thus facilitating its reduction to powder. In large works the manure is usually allowed to pass direct from the mixer into a special chamber, called the 'hot den,' where it remains for a period of one to four days, according to the demand. If it is too thin, some gypsum is generally added as a drier.

After being delivered into the 'hot den' the manure continues to give off offensive fumes, until its temperature has fallen. Hence this den must be made air-tight, and the openings into it be capable of being accurately closed when it is in use. By being allowed to cool in the den, moreover, a good deal of the vapour is retained, which is spread around if the manure be manipulated in the open while still hot and damp.

But even after two to three days' retention in the 'den' the temperature of the manure is still high, and when being dug out it may give off large quantities of offensive vapour. Ultimately the manure is pulverised, in large works, by machinery, and filled into gunny bags, in which it is sold.

The whole process of manufacture of 'superphosphate' is more or less offensive to the sense of smell. The presence of the organic materials from which the manure is to be made, of finished and fuming manure, and the very premises themselves, which are permanently employed for the production of the manure and continuously exposed to the action of these vapours, all make the special smell an all-pervading influence. Still, in well-managed works it would not be justifiable, as a rule, to say that the effluvium is a serious nuisance to the average man, and in the ordinary sense.

The nuisance is often complained of even before the materials reach the works, owing to the stench caused during their conveyance there. This can be obviated partly by their being brought as far as possible in a fresh state, and without waiting for their accumulation to form a large consignment (which means also increased time given for putrefaction), and more completely by their being brought in proper air-tight receptacles. The night-soil 'pails' in various towns are sufficiently well fitted to allow of their being conveyed full and in large numbers through the streets without any nuisance being caused. When received at the works the materials should be properly stored. Gypsum thrown on the bones acts as a good deodorant, and charcoal, ashes, and dry earth are also beneficial. There should be proper cesspools or other receptacles for the reception of the night-soil.

The highly irritant vapours which arise in the mixing and are discharged from the 'hot den' may be dealt with on the same principles as already referred to in treating of effluvia from other sources, i.e. by fire, water, or air: combustion, solution, condensation, and dilution. The vapours may be conducted by a flue and fan into the furnace, or if necessary the whole den should be within a well-built shed, and the vapours between the two might be dealt with in this way. Condensation can be very efficiently effected by means of a long flue in which the vapours, hydrofluosilicic acid, arsenic, offensive organic gaseous compounds, &c., may be condensed, and never reach the chimney at all, so as to be discharged into the air. In some large works no less than 440 feet of condensing passages have to be traversed before the chimney is reached. The length and efficacy of this can be greatly increased by the insertion of faults to compel the vapours to traverse a tortuous course. The vapours may also be treated more cheaply, but not more effectually, by the cold-water shower-bath ('scrubbers'), all non-absorbed gases being drawn into the boiler fire.

'Poudrette' is the name given to a manure in the form of a dry powder, of a brownish colour, prepared from night-soil treated with sulphuric acid. Sometimes other ingredients are added, or may even predominate, for the term is not applied to a specific compound, but its commonest signification is that stated above. The processes used vary considerably. In the form employed at the Corporation Works of Manchester, Rochdale, Warrington, and other 'pail' towns, the contents of the pails are thrown into a steam-jacketed boiler provided with a revolving stirrer to prevent incrustation, and holding some 400 gallons, in which they are desiccated in from four to six hours. The desiccated excrement ('poudrette') is discharged by an opening in the bottom of the boiler. The steam in the jacket is under a pressure of about four atmospheres. About thirteen pounds of sulphuric acid are added to every hundredweight of excrement for the purpose of fixing the ammonia. Fish-offal (heads, guts, &c.) ground in a mortar mill and other

waste are sometimes added, and thus a useful way is found of getting rid of a troublesome and offensive material. About 92 to 93 per cent. of the weight of material is lost during the desiccation.

The vapours from the boiler are drawn off, and in some cases are condensed in a cold shower-bath—in one case in a pipe run along the bottom of a stream —and it is certainly possible to conduct the whole process without the least nuisance either inside or outside the works.

In another process, the acid is added to the excrement in the pails, which is then thrown into a Milburn's desiccator (patent July 30, 1872, No. 2266), from which after being partially dried it is removed to a hot drying-floor, and is subsequently broken up and packed for sale.

According to another process, to a charge of some 550 gallons of excrement eighty pounds of magnesian limestone are added and the whole is distilled. The ammonia is conducted into a saturator containing brown sulphuric acid, and is there fixed. The offensive vapours, after serving to partly raise the temperature of the excrement before it is thrown into the boiler, are condensed and run into the drains. The sulphate of ammonium recovered is a valuable item, and it serves to reduce the working expenses.

The importance, in obviating the nuisance on such works, of a high chimney with powerful draught, and of a long flue, to the efficiency of which a good fire will greatly contribute, cannot be overestimated. It should further be a general rule that the whole of the operations should be conducted within a large, airy, closed building, except where some obvious impossibility exists to this being done; and this will be very rare.

STORAGE AND TREATMENT OF VARIOUS MATTERS WHICH MAY BECOME A NUISANCE

In large towns it is very difficult to avoid the accumulation of various materials which, harmless while fresh, may become most offensive, and a source of danger to health, when stored for some time.

Sanitary authorities are usually very unwilling to give much assistance in the removal of what is termed 'trade refuse,' and seem to imagine that a fine stroke has been made when they refuse to assist dealers in the removal of an accumulation of stinking fish-heads and guts, or of rotten fruit and vegetables from the same premises from which they are bound by law to remove night-soil. The Sanitary Authority may be within their rights, but are they benefiting the public by this action? Private individuals have not the means of getting rid of offensive matter of this kind, and they shirk the difficulty by letting the nuisance increase; further, it is more than questionable whether they should be allowed at their free will to pitch it into the first convenient corner, quarry hole, or ditch. It was for such reasons that the law was made to encourage sanitary authorities to remove night-soil, because they can do it better than private individuals, and have, or should have, means of disposing of it, if not at a profit, at least so as to diminish the cost of removal. The rapid disposal of such materials is for the public benefit, and no body of ratepayers would ever object to the Local Authority doing the work.

Manure

Among the offensive things stored about houses is manure, chiefly horse-manure. For some inscrutable reason the dung of animals has come to be regarded by the public as almost unobjectionable, while the sight of a few ounces of human excrement will sometimes cause quite an uproar.

Horses must be kept in towns, but the accumulation of their dung is not necessary, and is objectionable. When such manure is allowed to accumulate to a large quantity its removal is very offensive, and the stench often most pungent and far-reaching, and is quite capable of passing through ordinary brick walls, to say nothing of doors, windows, and chimneys.

Dung-heaps should not be tolerated in the populous parts of towns, and more particularly in the very poor parts. Removal every two to three days should be insisted on, and, like night-soil, it should be removed at night; the place where it lies in the yard should be sheltered from the rain, and should not abut on the wall of any dwelling-house.

The custom of making grooms, stablemen, &c., sleep in rooms over the stables is certainly objectionable—not entirely because the companionship of a horse is injurious to a man, but mainly because stables are generally situated in places not fit for men to live in, and especially so in large towns, where land is very dear. In London the so-called 'mews' are hotbeds of disease, owing to the foul air and the generally uninhabitable condition of the places from accumulation of manure and dirt.

Bones

Bones soon become offensive if kept. The grease attached to them becomes decomposed, capric, caprylic acids, and butyric, and other products of putrefaction being formed, and these give off very disgusting smells. They are often stored in private houses until quite putrid, and then the 'rag-man' usually gets them, and conveys them perhaps to his own home, where they may lie for months, before he finally disposes of them to the bone boiler or manure maker.

The best mode of preventing this nuisance is the absolute prohibition of keeping bones in quantity in any house; rag-pickers should be obliged to dispose of them at once, without storing them for any time in their homes. In private houses they should be burned, like all garbage, or be kept as far from the dwelling-house as possible and in some well-covered receptacle, but, no matter how kept, it is difficult to keep down a stench, if kept any time.

The health may undoubtedly suffer from the effects of exposure to this nuisance.

Fish

While the smell of fresh fish is pleasant, that of stale fish is horrible. 'Fresh' is a relative term, and really fresh fish—that is, fish not more than a day or two after being caught—is unknown in most of our large towns. The great bulk of the fish in England is not landed until it has been a week or even longer out of the sea. The fishing-boats from Grimsby and other great fishing ports go to sea and as a rule do not return for some seven to ten days. The fish are usually kept in ice during this time, but are sometimes kept alive in tanks. The herring fleets are escorted by special boats, which convey these delicate fish to land at shorter intervals.

Hence it is not surprising that the fish which the salesman declares has 'only arrived to-day' may go bad the next day.

The smell of bad fish is most adhesive, and the nuisance is increased by the detachment from the fish of the scales and slime, which stick to everything and putrefy. Extreme cleanliness and the rapid removal of all garbage is the essential condition of prevention of nuisance from fish.

The difficulty is increased by the large amount of *débris*, guts, skins, heads, tails, &c., which are necessarily produced in the way of business. There

is seldom adequate provision made for the disposal of these things; they are allowed to accumulate and rot, and they spoil the good fish. The Sanitary Authority should be ready and willing to assist in getting fish-dealers out of their difficulties by removing all their refuse.

Fish refuse may be advantageously disposed of without nuisance by grinding it in a mortar mill, mixed with lime and soot or ashes, for manure. Vegetable refuse may be also ground with it.

Like other filth, decaying fish may be injurious to health.

Fruit and Vegetables

Fruit and vegetables are liable, especially in summer and damp weather, to decay, and then become offensive. The immediate removal and destruction of decayed fruit is the only step to be taken, except the preliminary application of deodorants.

Vegetables require to be stored in cool, well-ventilated cellars, where they should be examined from time to time and the decaying ones removed.

The health may be injuriously affected by the emanations from decaying fruit and vegetables.

The condemned material may be utilised as manure, and for this purpose should be conveyed to and kept at a suitable distance from the outskirts of the town. A considerable quantity of it may also be more expeditiously utilised by grinding it in a mortar mill with fish *débris* (q.v.). Attempts have been made to get rid of the great mass of vegetable waste that accumulates in towns by calcining it in a special form of kiln, and the results have been satisfactory, except from a pecuniary point of view.

Eggs

On the premises of large dealers in eggs, who dispose of vast numbers weekly in the ordinary way of business, there is always a considerable number of rotten eggs, which are very offensive. Careful keeping in a cool cellar, with supervision, and the early removal of bad material, with the use of chlorinated lime, are the means to be adopted to avoid further evils.

Rags

The rag-picker is the symbol of the lowest stage of civilised life, except the pauper. His business is to fill his bag with refuse of every kind, rags, bones, scraps of meat, old clothes, &c., which he does regardless of quality, and to sell them. The bones he sells to the bone-boiler, the rags he collects for sale to the paper-maker; however, he rarely does this directly, but through a middle man. The latter often carries on business in an extensive way, exporting the material to distant countries: he stores and roughly sorts immense quantities of rags in premises which commonly are as dilapidated as the 'raw material' of his trade. The rags, collected from the gutters, ash-pits, and any other place where they are found, often give these stores an abominable smell. It is surprising that infectious disease is not frequently traceable to these places, as the quality of the rags is never questioned, and they must often come from infected premises. Small-pox and woolsorters' anthrax have been traced to infection from rags.

That all such places should be under the watchful care of the Sanitary Authority is obvious. The stores and contents should certainly be disinfected from time to time, and the use of lime-wash should be insisted on. Every

effort should also be made to prevent infected articles—bedding, old clothes, &c.—being deposited in such places until they have been rendered harmless by disinfection.

CARPET-CLEANING

The knowledge that infectious virus is a tangible thing, emanating from the infected person, and that it may be found deposited on carpets and other articles of furniture, makes it obviously improper that carpets should continue in the old-fashioned way to be shaken and beaten in the streets and yards, or shaken out of the windows. Apart from the danger of infection, there is the nuisance from the dust. In most towns of any size there are now carpet-cleaning establishments. These places are sometimes a source of annoyance from the noise of the machinery, as well as from the dust, which is in some places allowed to escape from windows but little elevated above the street. This should never be permitted. The dust should either be drawn by a fan, &c., into a high chimney, whence it will be rapidly blown about through the air, or, what is much better, be drawn under and into the boiler-fire, where it will be destroyed.

HAIR- AND FLOCK-PICKING

Unfortunately it is not the general custom to have beds, pillows, feather quilts, and such articles opened up and cleaned from time to time. Such things are often used for generations in a family without ever being taken to pieces, repicked and cleaned, and not infrequently are sold and bought and treated in the same way. And yet a moment's consideration will convince that they must become laden with dirt, if not with infectious matter. Observation of the process of picking an old mattress would astonish most people by the clouds of dust (= dry filth) with which it is laden. There is no doubt that pathogenic organisms remain quiescent in such receptacles, and become active and dangerous when favourable conditions arrive; this has been proved by experiment.

This work is usually done by hand in the houses of poor persons. It is greatly to be desired that it should become a regular practice to have all such articles cleaned from time to time, and that suitable establishments, where the work would be done by machinery, should be erected in all towns.

STREET SWEEPING

The maintenance of the streets in a clean state, free from dirt and dust, is one of the most important public sanitary arrangements, second only to drainage and sewerage, although it is very unusually looked on as of such value. That the surface of the streets should be hard, smooth, and impervious is of the utmost importance, not only for the convenience of traffic, but for the prevention of the accumulation of filth, which too often is the parent of disease, as well as of discomfort.

It must be remembered that the area of the streets is considerable; that they are continually befouled with excrement of healthy and diseased animals, and not infrequently of human beings, and receive offal of every kind from the houses; in the poorer parts people commonly throw their slops, sweepings, and every kind of rubbish into the street. The streets are subject to those changes of dryness and moisture which are most favourable to putrefaction; they are continuously traversed by the people, and are

the playgrounds for the children of the poor, and often are the only place where the adult poor can rest in the open air after work is over. All day long the door of the poor man's dwelling-room opens direct on to the street (usually this room is too dark and close to be habitable if the door were kept shut), and all day his family live almost in direct contact with the street and its emanations.

Ordinary mud is practically not very different from sewage, yet we commonly tolerate during many months of the year acres of streets covered with mud, more or less solid, evaporating its moisture and sending its stenches into our lungs and houses. When dry weather ensues the dry mud is converted into dust, and penetrates bodily into our mouths (to be swallowed) and noses (on its way to the lungs) and spreads itself over every part of our houses, where it deposits itself on our food, furniture, walls, &c.

The direct connection of disease with the existence of acres of evaporating slush in our streets, or with clouds of dust, has never been established. But a moment's thought will convince that it is more difficult to conceive these conditions as being harmless, than to realise that they can continue with impunity.

Hence the importance of the work of the street-sweeper. His work, being usually regarded as of very secondary importance, and as being mainly required to prevent mechanical obstruction from mud, or to check the complaints of the public as to dust, is seldom properly done. The usual way of removing dust is to try to sweep it into small heaps while perfectly dry, and possibly while a brisk wind is blowing, and to put into an open cart so much of the heap as the wind does not blow away, and to remove as much of the cartload as the wind leaves in it to the tip, or depôt for mud and manure, if one exist in the town. This is the ordinary mode of procedure, and it is calculated to aggravate rather than lessen the evil. It encourages the blowing about of the dust, and the sweeper is only an unnecessary expense. The dust should always be damped before the sweeping is done.

But the difficulty with the dust would be greatly lessened if the mud, which is so easy to remove, were not allowed to accumulate to form dust. The removal of mud is a mere mechanical labour, much easier than the removal of the dust.

During rain the sweeper should be at work assisting the rain to clean the streets. But the mud should be carted away at once, and not left lying in heaps on the roadside until it has been spread over the surface again by the traffic, as is very commonly the case, or until it has been converted into dust during the next dry weather. The mechanical sweepers drawn along by a horse are excellent for this work.

The suggestion to use for allaying the dust a solution of chloride of calcium, a very deliquescent salt, which retains much moisture, might in exceptional circumstances be useful.

But it should never be permitted to dissolve ice and snow on the streets by admixture of salt, because it forms an intensely cold 'freezing mixture,' injurious to boots and cruel to the wearer. The reality of this may be judged from the fact that such a mixture will give a reduction of temperature of from $+10°$ to $-18°$ C. (1° C. = 1·8° F.)

OIL-CLOTH (FLOOR-CLOTH), LINOLEUM

The term 'floor-cloth' was originally applied to a cloth covered with several layers of paint. But owing to certain defects—its coldness, slipperi-

ness and hardness—this substance is being superseded by kamptulicon, linoleum, and other substitutes, free from these defects, and quite as cleanly.

'Oil-cloth' is made of coarse canvas, usually manufactured from jute. It is suspended on a frame, which can be extended by screws so as to stretch the canvas, and on this it is coated first with size (to smooth the surface and also prevent the corroding action of the oxidisation of the linseed oil subsequently applied); afterwards a coating of very thick paint (commonly yellow ochre or red oxide of iron) is laid on with a trowel, and well worked in. Both sides are treated in this way, and when this layer is dry additional ones are similarly applied; last of all the pattern is printed on after the oil-cloth has been taken down from the frame. Blood and lime are sometimes used instead of size.

The drying is a tedious process, which used to take ten to twelve months, but it is now effected in rooms artificially heated to about 180° F. in one-fourth of that time. During the drying by heat very offensive vapours are given off.

Linoleum consists mostly of cork, finely powdered by machinery, linseed oil oxidised by exposure in a thin film to the air, and mixed into a sort of cement with rosin and Kauri gum. These ingredients are heated together in a steam-jacketed pot, provided with stirrers and an air-tight lid, a pipe from which conducts the vapours into the furnace. After a couple of hours the fusion is complete, and the 'cement' is discharged into a cold rolling-mill beneath, the roller being hollow, and kept cool in summer by cold water inside. The fumes given off at this stage are very pungent and offensive. After being rolled, the cement is ready for use, about 46 lb. being mixed with 56 lb. of the ground cork. They are mixed in a mill, with steam-heated rollers, the colouring matter being added, yellow ochre and barytes for brown, oxide of iron and vegetable black for red. Subsequently, after undergoing further processes of mixing, the compound is rolled out in sheets, and ultimately applied to the canvas made of jute, one surface only being covered, the other surface being protected by a layer of 'backing,' consisting of size and pigment, or of varnish. If necessary the surface is afterwards printed.

There is considerable danger of explosion at two stages of this manufacture: (1) during the pulverising of the cork, (2) when the 'cement' and cork are being mixed. The fine dust floating in the air is liable to ignite, and the cement may take fire spontaneously.

The character of the nuisance from both these manufactures is similar, almost identical, and arises from the vapour given off by the hot oil. In the hot drying-rooms for 'oil-cloth' it is hardly possible to breathe after the cloths have been drying for some hours. The vapours cause a great nuisance even at a considerable distance from the works. The only satisfactory way of treating them is to propel them by a fan into the furnace and burn them, the process being greatly assisted by preliminary passing through water.

MANUFACTURE OF VARNISH

A varnish is a substance which applied to the surface of an object increases its lustre, preserves it from damp and weather, provides a hard smooth coating, and improves the appearance.

There are various kinds of varnish: e.g. 'drying oils,' which become hard and resinous by oxidation in the air; oil varnishes, consisting of a resin and drying oil; compounds of gums, resins, &c., in a volatile liquid, which

by evaporation leave the precipitated solids as a glassy coating. 'Driers' are substances which accelerate the drying of oils, by themselves giving up oxygen, or by acting as carriers of atmospheric oxygen; oxide of manganese and oxide of lead are among the substances commonly used for this purpose.

The principal resins used to make varnish are true copals, animi, dammar, kauri, &c.

The following is the usual process of manufacture. The resin is melted in a deep, narrow pot either by a coal fire or gas, and when fusion is complete the action of the heat is discontinued (either by removing the fire or the pot), and the oil (linseed oil commonly), which has simultaneously been heated to about 600° F., is poured on the melted resin and stirred. The liquid is now boiled in a shallow open pot, it being desirable at this stage to expose it freely to the air, contrary to what is needed during the melting of the resin. If necessary the mixture is thinned with turpentine when cool. Sometimes the resin after being melted is cooled and subsequently dissolved in the oil by heat, or the raw resin is fused in the oil.

The vapours given off during the manufacture are generally very offensive and far-reaching, and are complained of as causing headache, malaise, &c., by those exposed to them even at some distance.

The annoyance is due partly to the vapour from the boiling oil (acroleïn), partly to those from the melting resins. The most effective preventive is the condensation, either through a 'continuous condenser' (similar to that used for condensing the impurities in coal-gas) or in water; or combustion in a fire may be resorted to; this, however, is an extravagant method, as the condensed vapours yield products useful in the manufacture of Brunswick black.

THE BOILING OF OIL

All oils have not the same properties as 'drying oils;' some, on exposure to air, absorb oxygen, lose their greasiness, and become dry and hard more readily and completely than others; and it is the possession of these qualities which constitutes a 'drying oil.' This valuable property of oxidising and drying is increased by (1) exposure to the air in a thin film; (2) heating, or as it is improperly termed, 'boiling;' (3) the addition of 'driers' (substances which accelerate the desiccation by parting with some of their own oxygen, or acting as carriers of atmospheric oxygen), the chief of which are sulphate of zinc, peroxide of iron (umber), and protoxide of lead (litharge). The first acts by assisting the separation of the vegetable albumen and substances which hinder the drying, while the other two are oxidisers.

Linseed oil, being one of the most important commercial 'drying oils,' is the one specially referred to in the following observations.

In the ordinary process it is boiled in an open iron vessel, heated by a fire, sometimes in the open, sometimes under cover. Such pungent vapours are given off that the workmen are seriously incommoded if they are freely exposed to them. At a certain stage it is advantageous to subject the oil to a draught of air, as it hastens the result. A still more effectual method is to blow air through the mass of the hot oil. The open fire may with great advantage be replaced by steam applied by means of a jacketed pan.

The vapours given off are very pungent and irritating, affecting the eyes and causing nausea, headache, malaise, and vomiting, even at a considerable distance from the works.

The most effective method of preventing nuisance is to have the pot covered with a hood, from which a pipe, provided with a fan, drives the

vapour into a fire, either that of the boiler, or the one under the oil-pot itself. The nuisance is so great that, if necessary, a special hot coke fire, connected with a high chimney, should be provided to destroy the vapour. It is usual to ignite oil which is intended for making printer's ink, whereby the nuisance of smoke is superadded to irritating stench. This, too, should be done under a proper hood connected with a ventilating pipe leading to the chimney.

PAPER-MAKING

Paper is composed chiefly of cellulose, more or less purified. From the thirteenth century, when rags were first used for paper-making, up till 1856, when esparto grass was introduced, cotton and linen rags were almost exclusively used for paper-making. Hemp, old ropes, straw, wood made into pulp, canes, bamboo, waste paper, and many other substances are now used for the same purpose.

The collecting and storing of rags, considering the character of the places they come from—infected houses, filthy hovels, &c.—even if mainly done for the purpose of paper-making, requires mention here as an important sanitary question. Care must be taken to keep them dry, as they may heat and ignite spontaneously through slow combustion.

The preparation of rags for paper begins with dusting them in a 'thrasher,' a machine in principle similar to the 'willowing machine.' After this they are sorted and cut, usually by hand, into pieces about two to five inches square, and they are again dusted in an agitator, after which they are boiled, usually with carbonate of soda or caustic soda, or a mixture of both.

Next they are bleached, either by chlorine, which is passed into a closed brick chamber, in which the rags are placed, or by the alternate application of bleaching liquid and acid.

The subsequent treatment does not differ essentially from that of esparto grass, the preliminary treatment of which will next be described. After a preliminary picking out of impurities, the grass is boiled with caustic alkali in a boiler with a perforated false bottom, steam entering beneath the false bottom and forcing or 'vomiting' the water up a wide tube, so that it is kept in constant circulation. This boiler is necessarily kept closed fast by screwing down the door.

After a time the liquor, which is very foul and contains resin, silica, &c., extracted from the grass, is run off into a store well, and fresh water is poured on and the boiling is repeated, after which the grass is reduced to pulp by machinery. The manufacture of paper from the pulp does not require mention here.

The recovery of the soda from the wash liquor is an important economical operation, and is one of the most offensive parts of the whole manufacture. The process employed consists practically in the evaporation of the liquid, and subsequent incineration of the residue, during which carbonic acid is formed from the vegetable matter, and combines with the soda to form carbonate of sodium. This when treated with lime forms caustic soda.

The vapours given off during the boiling of the grass, and from the hot liquor and grass after removal from the boilers, cause an unpleasant odour which has been compared to senna, and sometimes complained of as a nuisance by neighbours. This can be entirely prevented by condensation in cold water, the hot liquor being run in a coil of pipe through the water. Cold water applied at once to the grass, after it is boiled, will entirely prevent the unnecessary annoyance from vapours given off from it while cooling. The

hot liquor should be run into a cooling tank, there to remain well covered in until quite cold.

But the recovery of the soda leads to a greater nuisance, partly from the vapour given off during evaporation, still more from the pungent empyreumatic fumes produced by the ignition of the mass. The vapour should be conducted by a flue into a tall chimney. The fumes produced during incineration should be conducted under and into the fire.

Paper is coloured with a great variety of substances, of which the principal are: For blue, cobalt blue, ultramarine, Berlin blue, indigo-carmine, &c.; for yellow, chrome yellow, or acetate of lead and bichromate of potassium, yellow ochre, yellow ultramarine, &c.; for green, Schweinfurt, or Vienna green, Berlin blue with chrome yellow, &c.; for brown, umber, &c.; for red, madder lake dissolved in ammonia, red ochre, &c. The aniline colours are also used as paper dyes. For some few purposes the pulp is mechanically mixed with the colouring matter. The use of poisonous colouring matters should be absolutely forbidden, as being dangerous and unnecessary. As fine a green can be obtained now with harmless colours as with arsenic.

The use of paper coloured yellow with chromate of lead, red with minium (red oxide of lead), or green with arsenite of copper has been specially forbidden by some Continental Governments for wrapping roasted chicory, because, this being a very hygroscopic substance, the poisonous colouring matters of the paper may get dissolved by the moisture and lead to poisoning. The same precaution should be taken with regard to papers used for wrapping sweets, as children are liable to lick the papers.

INDIA-RUBBER MANUFACTURE

In this manufacture, and in the process of *vulcanising*, offensive odours of sulphur compounds are liberated, intermingled with those of tar oils, creosote, &c. These may be perceived at some distance from the factory, and are persistent and disagreeable. The means to be adopted are to conduct the boiling operations in covered vessels, to use a ventilating fan, and to pass the effluvia through a heated furnace.

ANTHRAX [1]

This disease, which commits terrible havoc among the flocks and herds in some countries, is comparatively rare in England. But there is some reason to believe that it is much more prevalent among our stock than one would suppose from the official returns made to the Agricultural Department of the Privy Council, and more deaths of men and women are due to it than appear in the published returns of deaths.

All the more important domesticated animals are susceptible to anthrax, including the cow, sheep, and horse. It is rare among pigs, and old dogs are little susceptible; while puppies take the disease readily.

Workmen engaged in any capacity about infected animals, or the skins, wool, offal, &c., of such are liable to infection. Hence it is most frequently observed among herdsmen, skinners, men who unload cargoes of hides, slaughtermen, and also among those who manipulate various wools and hairs, chiefly foreign, which have been directly derived from infected animals, or have been packed with infected material for the purposes of transport. Anthrax prevails extensively in parts of Russia, Turkey, and Persia (both

[1] See Article by the writer in the *Encyclopædia of Practical Medicine*. London: Churchill.

Asiatic and European, and parts of France and Germany. It is not at all so common in North as in South America. The most dangerous wools imported into this country are from the districts around Lake Van and from Persia.

In the manipulation of damp materials, such as hides, the infection is undoubtedly acquired by direct inoculation through breaches in the skin, and it is improbable that it is, unless in exceptional cases, acquired by swallowing. But in the manipulation of dry and very dusty wools and hair there is liability of infection in any of three ways—either by inoculation through wounds in the skin, by swallowing, or by inhalation. It is not necessary to assume that in the case of virus which has been swallowed there must be a wounded surface in the course of the intestinal tract, where absorption takes place. It has been shown by Koch that the spores of anthrax may be absorbed directly by the intestinal epithelium, and cause general infection in this way.[1] Although the bacilli of anthrax are capable of being destroyed by digestion, the spores are able not only to resist the action of the gastric digestive juices, but may pass with impunity through the whole intestinal tract, if not absorbed into the tissues *en route*.

Woolsorters' disease, which has attracted considerable attention, is so characteristic that it may with advantage be referred to in some detail as illustrating the mode of infection and the character of the disease. It occurs as a local disease, an external sore, with or without general symptoms, or the latter being present there may be no external sore.

That woolsorters were liable at times to suffer death and illness of a peculiar kind was long known, and especially was this observed in the Bradford district after the first importation of alpaca, a material unknown there until about forty years ago. It was mainly owing to the indefatigable exertion of Dr. J. H. Bell, of Bradford, that the true nature of the disease was ascertained to be anthrax.

The woolsorter is a person who divides the wool of a fleece into 'sorts' or classes of various quality, the coarser and finer portions being placed together in separate bundles. For some purposes a fleece, e.g. of mohair or alpaca, will be 'sorted' into as many as six or eight 'sorts,' or as few as a couple. The greater the number of sorts, the finer will be the character of some of them. Fleeces of English, colonial, and other sheep's wool are also 'sorted,' but usually into but a small number of 'sorts.'

The 'sorter,' dressed in a cotton overall, termed in Bradford a 'brat,' stands at his work before a sort of counter locally termed a 'sorting board,' which has immediately in front of the sorter an opening covered with a movable wire grating termed a 'hurdle.' The sorting of the wool is done directly over the *hurdle* and the dust and other fine matter fall through it, resting on the bottom, which is a few inches beneath the grating ('hurdle').

The sorting-rooms are often very large, the 'sorting-boards' being placed along the walls, opposite the windows. As many as thirty to forty sorters may be engaged in one room. The rooms are usually bare of all other furniture than the 'boards;' and too commonly the greater part of the floor space is occupied with stored bales of wool.

When dry, dusty material is being sorted, such as alpaca, mohair, and camel's hair, there is always a good deal of dust in the air of the room; but

[1] This fact is in Koch's opinion a critical objection to the general adoption of Pasteur's protective inoculation of animals against anthrax. He considers animals may be protected against infection arising from cutaneous inoculation; but that this does not impart protection against intestinal infection.

when sheep's wool is being sorted this is not the case, owing to its greasiness. The prevalence of this dust may not only be judged by the eyes and touch, but in a room which is not kept clean can be noticed by the quantities adherent to the ceiling and walls.

It is usual in some cases to have the bales or large packages of wool covered with coarse sacking, before they reach the sorting-room, opened. The contents are considerably compressed in packing, and when the bales are opened and the fleeces are shaken out there is a great cloud of dust raised, if the material is of the character referred to (mohair, alpaca, &c.) When the bales are opened in the sorting-room under such circumstances, the effect is to distribute immense quantities of this fine dust throughout the room. Within the bale each separate fleece is made up into a kind of rough bundle apart from the others. Even an inexperienced eye must notice that some of these fleeces or some parts of them are often covered with a good deal of filth, mud, dung, &c., though as a rule the smell is not offensive. There is the odour peculiar to the wool or hair, but even in the case of bales which undoubtedly contain anthrax virus there is very rarely anything which could be termed a stench.

The history of a case of woolsorters' disease is very characteristic, though mainly owing to the absence at the outset of anything indicating danger to the inexperienced. The sorter goes to his work in his usual health; after an hour or so, it may be, he feels giddy or 'queer;' but believing the feeling will pass off he persists in working until at last he is obliged to go home. 'Tightness' in the chest is a common symptom at the outset, and there are generally complaints of feeling chilly—indeed, the patient is usually convinced he has caught cold.

In serious cases the fatal end may come in twenty-four hours, and it is rarely postponed beyond three to four days. But there is no doubt that many persons have slight attacks, with all the symptoms usually observed in fatal cases, and are quite well in a few days.

The further course of serious cases is chiefly marked by increasing prostration. The pulse becomes feebler and more rapid, the breathing slow and shallow, and the temperature falls.

The following are the precautionary regulations originally drafted by the writer, and after modification agreed upon, as necessary for the prevention of woolsorter's disease, by the Sanitary Committee of the Town Council of Bradford, by committees of the manufacturers and woolsorters, and by the coroner's jury upon the inquest held on the body of Isaac Saville in 1884:—

1. All bales of wool or hair shall be opened by a person skilled in judging the condition of the material, any woolsorter to be deemed such person if willing to perform the duty. If he find the contents unobjectionable they shall be sorted in the ordinary way. If, on opening any bale, dead or fallen fleeces or damaged materials are found, such bale shall be at once taken from the room where opened, and dealt with as noxious. All Van, Persian, damaged wool, fallen fleeces, and foreign skin, wool, or hair, shall be deemed noxious and shall not be opened in the sorting-room. Noxious wool or hair shall, before sorting, be thoroughly saturated with water and then washed in hot suds, rolled and sorted while damp, or if steeping would be injurious to the article, or would render difficult the working of the material, then it shall be disinfected.

2. No noxious material (alpaca, pelitan, or East Indian Cashmere) shall be opened in the sorting-room, but in a place specially set apart for the purpose, separate and distinct from the sorting-room, and all such material shall be opened over a fan by a person capable of judging the condition of the material.

3. The sorting-rooms for all classes of mohair, camel hair, Persian, Cashmere, and alpaca shall be provided with extracting-fans so arranged that each sorting-board shall be independently connected with the extracting-shaft, in order that the dust arising from

the material being sorted may be drawn *downwards*, and thus prevented from injuring the sorter.

4. The dust collected by the fan must not be discharged into the open air, but be received into properly constructed catch-boxes. It must be afterwards burnt. This must be attended to at least twice a week. The sweepings from floors, walls, and from under the hurdles shall be similarly treated. All pieces of dead skin, scab, and clippings or 'shearlings' must be removed weekly from the sorting-room, and must not be dealt with or sold until they have been disinfected.

5. All bags in which wool or hair has been imported shall be picked clean and not brushed, and such bags shall not be sold or used for any other purpose until they have been disinfected.

6. No sorter having any exposed open cut or sore upon his person shall be allowed to sort.

7. A place shall be provided in which the sorters can leave their coats outside the sorting-room, or in some suitable place covered over, during working hours.

8. Proper provision shall be made for the keeping of the sorters' food out of the sorting-room, or in a closed closet therein, during working hours. No meals shall be taken in the sorting-room.

9. The sorting-rooms shall be well ventilated, by fans or otherwise; but as this cannot be effectually accomplished by open windows only, power shall be employed to secure *downward* ventilation, so arranged as to protect the workmen from draught. The windows shall be kept open during meal hours. The sorting-rooms shall be warmed during cold weather.

10. No wool or hair shall be stored in the sorting-room, unless the same be effectually screened off from such room.

11. The floor of the sorting-room shall be thoroughly sprinkled with a disinfectant, so as to allay dust, and swept daily after work is over. The sorting-room shall be thoroughly disinfected and the walls thereof limewashed at least once a year.

12. Requisites for disinfecting and treating scratches and slight wounds should be at hand in the sorting-room, as thereby fatal consequences may be avoided.

13. Proper provision shall be made for the sorters to wash in or near to the sorting-room.

14. A copy of these precautionary regulations shall be hung up in a conspicuous place in every sorting-room.

Town Hall, Bradford, August 8, 1884.

A great deal of benefit has been derived from these regulations, imperfect as they are. The necessity of compromise in getting such a set of regulations agreed to by persons representing very diverse interests is obvious, and such compromise unavoidably weakened the original draft proposals. The great boon gained was the recognition of certain materials as being dangerous, and the consequent responsibility attending their use.

In clause 1 it is obvious that 'any woolsorter' should not be deemed a person skilled in judging the condition of wools, &c. The object of selecting a skilled person is that he may be able to give notice to the head of the firm if the material is unfit to deliver to the 'sorters' for sorting. Such knowledge is not in the possession of 'any sorter,' but only of skilled and experienced men.

Further, it would be much better if it had been left optional to wash or disinfect any kind of wool, instead of specifying that some kinds shall be washed, &c., and some disinfected.

3. These materials are specified as being notoriously dry and dusty. A general regulation applicable to all dusty material would be preferable. There is no reason why the extraction might not be horizontal, instead of downwards, if the circumstances of the building make such more suitable. The object is to keep the objectionable dust from rising.

4. The general regulation to burn all dust is unreasonable and unnecessary. The dust from such material might readily be rendered harmless and valuable.

5. The object of this regulation is to prevent bags possibly infected by anthrax being sold and used for seating chairs, sofas, and other purposes,

and to prevent the creation of a great deal of dust in the sweeping of them.

7. The alternative of keeping the clothes 'in some suitable place' is objectionable. It is understood to mean inside the sorting-room, and the vague phrase 'suitable place' will often mean any unsuitable place. The sorters' coats, &c., should be excluded from the sorting-room.

8. Similarly in this regulation there should be rigid exclusion of food from the sorting-room.

9. The warming of the rooms is not only necessary as a general hygienic regulation in the sorting-rooms, which are often very large and lofty, but it is especially necessary for sorters, whose fingers may become numbed with cold, and they do not readily notice slight cracks and scratches, the existence of which is most dangerous.

10. The alternative here provided, as in other clauses, renders the regulation practically useless. The prohibition was needed—

(*a*) To prevent danger from infected wool stored in the room, often for months.

(*b*) To prevent sound wool thus stored from being infected by dust from other wool.

(*c*) To prevent the cubic space required by the sorters being unduly curtailed, and the free circulation of the air being impeded.

The 'screening off from the room' may be effectual, and yet all the real requirements of the regulation be set at nought.

THE CURING OF BACON

There is one part of this business which is liable to be very offensive, apart from the processes with which it is often associated, and which may themselves be offensive. This is the singeing of the hair of the pigs in preparing the flesh for bacon.

After the pig has been slaughtered, it is 'scalded' and washed, and then scraped to remove the hair, without singeing; but sometimes the hair is singed before the scalding. Sometimes this is done, on a small scale, with an ordinary instrument, such as is used for singeing horses, or an ordinary gas-flame is used. At other times the carcase is placed for a few minutes on a straw or a coal fire, or it may be suspended in the chimney so as to catch the heat from the fire.

The most complete apparatus, probably, is Denny's patent pig-singeing furnace; an arrangement by which with a revolving apparatus one carcase after another is introduced into the singeing place, the work being completed in about twenty-five seconds, and the greater part of the effluvium passes up the chimney.

The stench from the burning hair is very offensive, and is often allowed unnecessarily to become aggravated by the carcase being left still smoking on the premises. A bucket of cold water thrown over it stops the smell at once.

The drying of bacon is ordinarily effected merely by hanging it in a dry airy situation, as for instance near the kitchen ceiling. On a large scale it is accelerated by the use of special rooms heated to about 95° F., the heat being supplied by fires of coke, or smokeless coal in a fire-grate, or on a brick flooring in the centre, openings being provided in the roof or walls for the escape of smoke. The 'smoking' of the bacon and hams is effected by exposing them to the fumes of burning wood, above which they hang, and the

flavour is varied according to the wood used. Oak or elm shavings, or sawdust, are most commonly used.

The fumes from the smoking chambers are pungent, unpleasant, and may become a nuisance unless discharged into a chimney high enough to secure their diffusion. But the smell of the singed hair is the chief nuisance complained of in connection with this trade, and it can only be overcome by the process being conducted in a closed chamber, and so that the fumes shall be burned, or condensed, or both, and then discharged through a high chimney.

There must always be difficulty in carrying on this business, and others in which offensive effluvium is produced in crowded districts, and it is just in crowded poor places that such businesses are most commonly found in operation.

Another source of nuisance connected with bacon-curing is the brine, which is sometimes used too long, and even after it has become offensive is often allowed to stand on the premises until it is quite unendurable. The mode of avoiding this nuisance is too obvious to need further comment.

The preparation of American pork in this country to make bacon may be a source of annoyance from the warm liquor, in which the pork is steeped, undergoing putrefaction, and being discharged into the drains. This annoyance could be easily avoided. The process of preparing bacon from American pork consists in first steeping it for about twelve hours in water to extract excess of salt, then drying it in a hot, closed room, warmed by a charcoal fire, and subsequently exposing it to a current of air.

MANUFACTURE OF HORSE-HAIR

Horse-hair is chiefly used for making mattresses, stuffing chairs, making cloth for covering chairs, sofas, railway-carriage seats, brush-making, &c.

The hair used is by no means exclusively horse-hair, though generally known under that name. Cow-hair is used for the same purpose, but is generally of a finer quality than horse-hair. Pig-hair also is largely used, but not for weaving, being too short. As the treatment of all these hairs is practically the same from the sanitary point of view, they will be all included generally in this article.

The manes and tails of horses are the parts used, and the tails of cows.

Except the best quality of horse-hair, all these are more or less dusty and filthy. Sometimes the bales smell very unpleasantly. The hair has commonly dung, earth, &c., attached to it, and sometimes even bits of skin and even bones of the tail will be found attached.

After pieces of skin, &c., have been detached, the manufacture of long hair may be said to commence with the sorting, or dividing the hair into long and short, coloured and white. There is a good deal of offensive dust stirred up during this process.

The hair is then washed, and when dry is combed, which straightens it and removes short hairs (which are mixed with pig-hair and curled), and it is then further divided into lengths, the longest being set aside for weaving. The coloured hair is then dyed, the almost universal colour being black, while the white hair is bleached by exposure to the fumes of burning sulphur in a small closed chamber. The dyeing is usually done with logwood and protosulphate of iron.

The short hair is sometimes dyed and sometimes is not. If very dirty it is teazed and dusted in a 'willowing' machine, similar to that used in the

wool trade. This consists of a closed box, within which revolve one large cylinder and usually three small ones all being provided with spikes projecting from the surface. The hair being fed into the box, when the cylinders revolve it is tossed about and opened out, the lighter dust being removed by a fan, while the heavier falls to a false bottom placed between the true bottom and the cylinder. The fine dust is commonly discharged into the air—a very objectionable custom. The heavier dust is very good for manure, for which it is generally used.

Short hair which is to be dyed is commonly dyed with the dirt on. Sometimes it is 'willowed' first. It is dyed by being boiled with logwood in a large vat, commonly in the open, but (protected from the rain) by means of steam discharged into the water. After some hours sulphate of iron (green copperas) is added, the whole process lasting some six hours. The hair is then removed to another vessel and washed, and if necessary that which has not been previously 'willowed' is passed through a dusting machine. The liquor was formerly discharged direct into the sewers while hot, by which a very offensive smell was created along the streets, and often inside houses, as it ran through the drain-pipe. Now there is a statutory limit of 80° F., above which temperature liquids are inadmissible into sewers.

The hair is curled by being first twisted into a sort of rope by the curling machine; by two subsequent operations it is further twisted till it assumes a convoluted form, in which it is tied; it is then steeped in cold water for some hours, and on removal is placed in ovens at a very high temperature, after which the curl is permanent.

In the neighbourhood of such works there is often great annoyance created by the stench from the vapours of the dye-vat, and from the hot liquor discharged into the drains. The former could be entirely obviated by the use of a water-sealed lid, with hood and a flue conducting the vapours into a cold-water tank or scrubber. The discharge of the vapours into the chimney will be quite ineffectual unless it be of sufficient height. The only effect of discharging into a chimney insufficiently high is that, instead of those near the works being affected by the stench, it will be those at a little distance. The smell may extend for hundreds of yards, and is often of a very sickening character, causing nausea and malaise, and rendering it impossible to open doors or windows.

The remedy for the nuisance arising from the liquor discharged into the drains is not to discharge the liquor into the drains till cold, a precaution which should be taken with all fluids discharged into the sewers in large quantity.

A more serious evil is infection with anthrax (known as woolsorters' disease, charbon, malignant pustule), which undoubtedly occurs at times, and probably more frequently than is suspected. It is due to infection by means of virus attached to the hair from animals which have suffered from the disease. There seems no reason why all dirty hair should not be boiled and dyed before sorting, which would obviate the dangers of the dusty stage, and probably disinfect thoroughly. Little is to be expected from the suggested use of a respirator during sorting, because (1) the disease is by no means always taken by inhalation, but frequently by inoculation through scratches, and (2) workpeople will not wear respirators of any form so far known, finding them too unpleasant. (Cf. Precautions against Woolsorter's Disease, p. 932.)

B. BUSINESSES IN WHICH KNOWN GASES OR VAPOURS OF MINERAL SUBSTANCES ARE EVOLVED

MORBID EFFECTS ARISING FROM THE INHALATION OF GAS

Before referring to the notable and unmistakable reactions occurring in the body in consequence of the inhalation of toxic gases, a word may be said in reference to the action of certain gases, usually termed *indifferent*—i.e. those which, when mixed in certain proportions with oxygen, do not cause any decided morbid symptoms, provided the proportion of oxygen be not too small.

Those most deserving attention in this group are nitrogen, hydrogen, marsh gas, and olefiant gas (respectively termed in modern nomenclature methyl hydride, and ethylene).

Although the continued inhalation of a mixture of such gases with oxygen may give rise to abnormal symptoms, especially if the proportion of oxygen be low, it is not at all clear that the deficiency of oxygen is not the source of the mischief, rather than the presence of the other gases.

Methyl hydride may certainly be regarded as a truly indifferent gas. It seems that olefiant gas (ethylene) does possess certain toxic effects; at least certain unpleasant results of breathing the air of mines (coal) where it existed have been attributed to its action, though by no means with certainty.

A rabbit confined in an atmosphere containing 30 per cent. of the gas became narcotised in thirty minutes, its respiration having become tranquil after a period of excitation. The animal recovered completely after one hour. A pigeon exposed to a similar atmosphere died. It exhibited convulsive movements with its wings, difficult breathing, and lay with its head on one side; the pupils were dilated and the temperature diminished. The autopsy showed the heart and veins filled with fluid blood; the lung surface bright red, with some brownish marbling; the cut surface showed black hæmorrhagic spots.

Ethylene is distinctly an anæsthetic gas. The morbid condition known as 'miner's anæmia' has been supposed to be due to the continued respiration of air containing a considerable proportion of ethylene. It is more probable that it is only one of the factors which leads to this serious and mysterious morbid condition. When one considers the conditions under which a miner spends his working hours, in almost absolute darkness, in an atmosphere too often charged with moisture, or dust, containing many abnormal constituents besides the gas in question; further, when one takes into consideration the nature of the work, the position, often most constrained, lying on the back or side, &c., it will not seem surprising that some constitutions should suffer. Among the most notable pathological phenomena of this disease are the quantitative diminution of the blood-corpuscles, and their greater or less disintegration, as well as the diminished secretion of sugar in the liver.

MORBID CONDITIONS DUE TO THE INHALATION OF IRRESPIRABLE GASES

It is not possible to draw too exactly the line which separates irrespirable gas from those which are directly poisonous. By the former are meant gases which produce readily or immediately great irritation of the respiratory passages, generally leading in small quantity to cough, and in greater quantity to spasmodic closure of the larynx. This salutary closure of the respiratory

tract prevents the further entrance of the noxious agent. Of the rapid action of sulphurous acid gas, one of those included in the category, the writer can speak from personal experience.

He was about to disinfect the operating-room of a hospital to which he was surgeon, and had procured an alcoholic solution of sulphurous acid for the purpose. The room had been prepared by the closure of all orifices, except the door by which exit was to be made after the disinfectant had been poured on the dishes arranged for it. At the last moment the solution of sulphurous acid was poured out on the dishes, and the writer hastened to the door, but before reaching it he fell, completely overcome by the fumes. Had his fall not alarmed the nurses, who hurried to his help and dragged him from the room, the result would probably have been fatal.

Sulphurous acid (sulphur dioxide) comes into consideration in a variety of industries, in a greater or less degree—e.g. in the manufacture of sulphuric acid, alum, glass, catgut; in the manufacture of 'tin'—that is, really the tinning of thin sheets of iron; in bleaching of certain kinds, such as wool, cotton, silk, straw, &c.; in the preparation of certain kinds of 'preserved' foods (fruits, vegetables, meat, &c.) and on a very large scale in the preparation of hops. These last are 'sulphured' to make them keep when dried. Wherever coal is burned, or minerals containing sulphur are roasted, SO_2 is also produced.

No very specific characters can be attributed to the effects of inspired sulphur dioxide. Animals experimentally exposed to its action exhibit restlessness, followed by depression and convulsions, which terminate fatally. The heart and great vessels are found after death charged with blood, and the muscular irritability is diminished; the blood assumes a dirty brownish-red colour. According to Hirt, sulphur dioxide has a direct paralysing action on the vagus nerve, and affects the respiratory centre, sometimes as a stimulant, sometimes as a paralyser, death resulting from paralysis of this centre.

Weak dilutions of the gas (5–15 per cent. SO_2) paralyse the vasomotor centre rapidly, while strong ones (50–70 per cent. SO_2) produce this as a secondary effect after a preceding stage of excitement.

The morbid effects produced by continued inhalation of SO_2 in weaker dilution (e.g. 4–6 per cent.) seem at first to show themselves, not, as might be expected, in the respiratory organs, although acute catarrh of the respiratory organs is common enough, but in those of digestion. Even in a much weaker dilution than that named the depraved air causes an acid taste in the mouth, acid eructations, anorexia, irregularity of the bowels, and, as might be expected, effects on the general health corresponding to these evidences of impaired digestion. Hirt states that sometimes increased activity of the digestive organs is observed where there is only a weak dilution of the gas, but others, especially Eulenberg, deny this.

Hirt lays especial stress on one result of his experience—viz. that most commonly the continued inhalation of a weak dilution of SO_2 may not be directly capable of conviction of causing disease of the respiratory tract, but that it is eminently calculated to produce a morbid condition of that portion of the body, which ultimately leads with great certainty to disease.

In the bleaching of straw hats, these are loosely packed in a box and exposed to the fumes of SO_2 for some hours.

That workmen who are exposed in a confined space to exhalations which, when they escape into the open air, kill the plants in the neighbourhood, and cause great annoyance to those living near at hand, should suffer in their health is what must be expected. Although it may be impossible to apply a

chemical test, and show by a chemical reaction that the SO_2 is the cause, still common-sense and humanity alike claim for the workmen in such a case the protection of the law.

It is an obvious suggestion that workshops where fumes of this character are produced should be under strict sanitary supervision, and that they should be so situated as not to prove a nuisance or injurious to neighbouring houses.

Wherever workmen are unavoidably exposed to SO_2, it is most important to employ means to secure its being prevented accumulating in the place by proper ventilation, which will ensure the exit of the gas and the supply of pure air.

Should a dangerous amount of the gas be present in any place, various means may be employed to diminish the danger. First, of course, comes free ventilation ; but in addition it will be useful to use—

(1) Absorbent media, such as water sprinkled about, alkalies, &c : milk of lime is very useful ; metallic oxides—e.g. those of copper or iron ; organic substances—e.g. sawdust well warmed is also an excellent absorbent.

(2) Oxidising media—e.g. lead dioxide, manganese dioxide. Sulphuretted hydrogen also reacts with SO_2, with production of sulphur.

CHLORINE

Chlorine is used in various forms in enormous quantities in the arts. As a bleaching agent it is largely used for the rapid bleaching of cotton and linen goods (but not of woollen, silk, or straw[1]), bones, ivory, glycerine, also in certain kinds of printing on stuffs (Turkish red), and dyeing.

Chlorine is usually developed from manganese dioxide, sodium chloride, and sulphuric acid, the sodium combining with the sulphuric acid and liberating the chlorine. The prevention of the escape of chlorine from the vessel is a most important matter for the workmen.

Inhalation of chlorine for some time produces effects very similar to the inhalation of ammonia. But large quantities in the air (10–20 per cent. chlorine) quickly leads to inflammatory action in the respiratory tract, and even extensive pneumonia. Spasm of the glottis occurs, but soon relaxes, and is certainly not the cause of death, which seems rather due to paralysis of the heart. A rabbit placed in an atmosphere of chlorine in three minutes became dizzy and fell; and death ensued in five minutes, with slight convulsive movements of the extremities and deep spasmodic inspirations. The brown-red, black spotting of the lungs is characteristic of death from inhalation of chlorine. The finer bronchi are filled with a froth, and the mucous membrane of the trachea and bronchi are discoloured brown. The lungs may be in part condensed and firm to the touch. The blood is of a thick consistence, and is sometimes granular.

According to Hirt, chlorine workers suffer much in general health, from 450 to 500 per 1,000 requiring treatment during the year for internal ailments, not from actual chlorine-poisoning, which cannot be said to exist, but from results of its irritating action. The respiratory organs are the first to suffer, the irritating gas causing cough, sneezing, hoarseness, great irritation, and even inflammation of the larynx. The coughing fits may be so violent as to lead to bleeding of the nose, and even fatal hæmorrhage from the lungs. The action of the gas on the mucous membrane of the nose and mouth may lead to loss of both smell and taste. The general discomfort may increase

[1] See above

till giddiness occurs, and this may end in sudden asphyxia, which, however, usually terminates on exposure to a plentiful supply of fresh air. Death under such circumstances is not common.

Still though such fatal occurrences are rare, general bad effects result from continual exposure to an atmosphere laden with chlorine. The workmen lose their healthy colour, age quickly, and look pale or greenish.

The commonest form of internal disease among workmen engaged in this trade is acute catarrh, which may end in acute pneumonia. Where other diseases, or tendency to disease, exists (e.g. phthisis) it is tolerably certain that the continued irrritation of the respiratory tract will maintain a condition highly favourable to the progress of the disease.

As a protective, the inhalation of alcoholic solution of ammonia has been recommended. Eulenberg recommends in preference the carrying of sponges moistened with alcohol before the mouth and nose, and rightly condemns the inhalation of aniline (recommended by Balley). The use of the latter may prevent the pungent smell, and irritation of the throat, but by the formation of *chloraniline* may do serious harm to the workmen.

The frequent occurrence of pyrosis among the workmen is due, no doubt, to the actual swallowing of abnormally acidulated saliva. The indigestion due to this excess is responsible for much of the ill-effect above referred to as being observed among workers where chlorine is produced. Careful attention to dietary is obviously one of the hygienic regulations most needed.

BRICK-MAKING

Bricks, tiles, &c., are formed from a great variety of clays, differing greatly in physical character. The clay has to be ground and mixed with water, after which it is allowed to dry to the proper consistence. Sand, chalk, ashes, or fine coal, are added sometimes, and even the miscellaneous *débris* of dustbins. When bricks are to be burned in a kiln combustible matter is usually not added to the clay.

Bricks are burned either in 'clamps' or 'kilns.' The former method consists in building the bricks into a pile 8 to 10 feet high, with alternate layers of fine breeze (cinder), air-passages being left at suitable intervals. When a clamp (or pile) of sufficient size has been made, which may mean half a million to a million and a half bricks, fires are lighted around it, by which the breeze is ignited, and by this means the combustible matter in the bricks themselves is also put into a state of slow combustion. When this has been all consumed the combustion ceases.

When the bricks are burned in a kiln, fuel is used in much larger quantities than in the 'clamp' process. In some kilns the top is open, and the effluvium escapes; in others it is closed, and the smoke, vapours, and gases escape by a chimney. In the former the bricks are built up pretty much as in the clamp process, but a considerable space is left at intervals between the bricks to serve as receptacles for fuel, some of the orifices being closed by plaster to retain the heat at a certain stage. It takes about 12 to 14 days to complete the making of bricks by this process. The closed kiln consists of a low brick building, with openings at the top and sides for filling, stoking, &c.

Within these the 'green' bricks are built up, and they are so arranged that when at work the draft ascends inside along the walls and descends through the bricks to the flue leading to the chimney, the flue being underground; in other forms the chimney rises from the centre of the oven. The Hofmann circular kiln has acquired a deservedly wide reputation as one of the best for large work, as it requires little fuel and burns it thoroughly.

For smaller works other forms of close kiln are in use, which are a great improvement on the clamp process.

There is no town which is growing quickly where there has not been trouble from the effluvium arising from brick-making. That given off by the clamp process is sometimes very offensive, the degree depending a good deal on the nature of the material, the proportion of organic matter, and its character. The continuous issue of smoke at such a low level and its smell, which is sometimes pungent and very disagreeable, are the chief sources of complaint. Sulphurous acid may be present in a very appreciable degree. At the commencement of the burning the emanations are charged with watery vapour, and often with sulphuretted hydrogen, carbonic acid, carbonic oxide, carburetted hydrogen, ammonia, &c. Offensive empyreumatic gases are sometimes largely present also, arising from the combustion of organic matter. When bricks or pottery are glazed, the nuisance becomes much more serious both for the workmen and the neighbours. If salt is used, chlorine is given off; if sulphide of lead be employed, the danger arising from the lead and the sulphur fumes is very serious.

This last source of nuisance could easily be removed by avoiding the use of organic *débris* entirely, and using only small coke. The smoke nuisance is largely due in this case, as in ordinary boiler fires, to the utter recklessness with which the stoking is neglected, the red-hot and smokeless fires being from time to time damped down with coal heaped on, instead of small quantities being put on at short intervals. The watering of the coal before it is put on the fire has a very advantageous effect in diminishing the smoke nuisance.

The nuisance is sufficient to cause actual fainting, oppression of breathing, and other serious symptoms in persons much exposed to it.

MANUFACTURE OF PORTLAND CEMENT

Portland and Roman cements are two kinds of hydraulic cements manufactured in this country. Genuine Roman cement is made from pozzuolana, a ferruginous volcanic ash from Vesuvius and other Italian volcanoes mixed with lime; or from a combination of lime and trass, a kind of pumice from the Eifel district of the Rhine. This material simply requires grinding. In this country cement is made from the septaria[1] from the London clay and the Lower Lias formations, from cement stone of the Upper Lias, and from shale beds of the Kimmeridge clay. It is also made by the calcination of mixtures of lime and ferruginous clay. The septaria are calcined in open kilns, like limestone, but the process does not give rise to much nuisance.

The manufacture of Portland cement, however, causes a serious nuisance unless conducted with special precautions. It is made usually from a mixture of about eighty parts of chalk or rich lime and twenty of clay or alluvial mud. The materials are mixed wet, then dried, calcined, and pulverised. The clay used often contains much peaty matter, and even more offensive materials, which give rise ultimately to the great nuisance complained of.

The ingredients having been well mixed and brought to the proper consistency (in which state it is known as 'slurry'), are dug out and dried, usually on iron plates, heated either indirectly by flues from coke fires, or directly by the fires themselves. When dried the 'slurry' is placed in an ordinary kiln,

[1] Nodules of clay, ironstone, &c., internally divided into angular compartments (septa) by fissures, which are usually filled with a calcareous spar.

like that used for lime-burning, and calcined; alternate layers of 'slurry' and coke being deposited in the kiln, and then lighted, the 'charge' taking usually (according to size) some three to five days to burn out.

The nuisance complained of is due partly to smoke and vapour, partly to the smell, which is somewhat like that caused by brick-burning, but has also a strong similarity to the odour of burning bones or other organic matter, the character of the smell varying greatly, from very slight to very bad, according to the nature of the clay used.

People exposed to these effluvia complain of a nasty taste in the mouth, often of an acid character, of a dryness of the mouth and throat, and even of vomiting and oppression of breathing.

The smell arises during the drying of the 'slurry,' but then it is very slight compared with what is emitted during the calcining. It has been found that sulphuretted hydrogen and compounds of cyanogen, probably a cyanide of ammonium or sodium, a sulphocyanide, chloride of sodium, and empyreumatic compounds are given off during this process. The common salt given off in a state of very fine division increases the annoyance from the more serious gases given off. The effluvia vary, as has been stated above, considerably in different places, and do not everywhere contain all these dangerous and offensive ingredients.

The best mode of preventing the danger is to pass the vapour collected from the kiln by a suitable hood and flue, assisted by a fan if necessary, through the furnace, and thence into a tall chimney. Attempts have been made to deal with the nuisance by condensing and washing the fumes in a cold-water scrubber, but not always successfully.

LIME-BURNING

Lime-burning consists in heating limestone or chalk in a kiln, which causes it to decompose and form lime (quicklime) and carbon dioxide. Lime is not found free in nature, but it exists in enormous quantities in the form of carbonate.

The ordinary open lime-kiln is practically a sort of chimney, lined with firebrick or refractory stone, and narrowing to the bottom, where the lime is discharged. It is charged from the top with alternate layers of fuel and limestone or chalk, and is fired from below. Such a kiln may be worked continuously, more layers of fuel and limestone being charged above as the lime is withdrawn below.

Closed kilns are also sometimes used, similar to the Hoffmann brick-kilns (q.v.)

The nuisance from lime-burning is due partly to the carbon dioxide evolved from the limestone or chalk as well as from the coal, partly to the smoke, and also to the offensive fumes evolved from the fuel, which is burned slowly, and not briskly as in an open fire. Carboniferous limestone causes a much greater nuisance than other materials used for lime production.

Death may arise from continued exposure to the fumes, as when persons lie down to warm themselves, fall asleep, and die. Continued exposure to the fumes leads to very serious symptoms—debility, loss of appetite, great drowsiness, and general nervous derangement. The results are probably due to the carbonic oxide.

Much of the nuisance is due to the quality of the fuel, which should be good coal or coke (not inferior shaly material). Inferior coal causes greater nuisance, greater waste, and makes worse lime. Besides the use of better fuel, a tall chimney should be used to discharge the fumes at a sufficient height.

Spencer's patent kiln consists of two egg-shaped chambers, one above the other and communicating one with the other. The limestone is charged in at the top, and the fuel by openings made lower down. The heat from the lower chamber warms the stove in the upper before it descends into the calcining chamber.

CARBONIC OXIDE (Carbon Monoxide, CO)

This gas is formed when carbon burns in a scanty supply of air. It is a colourless, tasteless, and odourless gas, rather lighter than air (sp. gr. = 0·97). It is present in ordinary coal fires, the vapour of burning charcoal (from 0·34 to 2·54 per cent.), in ordinary illuminating coal gas and 'water-gas,' and in the gases resulting from explosions of gunpowder; it is given out in large quantities in the smelting of iron ores, in the making of coke and of wood charcoal. It is a deadly poison when inhaled, all the more dangerous in that it indicates its presence in no way to the sense of sight, taste, or smell, is not irritating to the respiratory or digestive organs, and that, exercising a narcotic and paralysing effect, it lulls the sensations and causes insensibility without arousing any desire or effort to escape the danger.

It is not often that accidents arise from inhalation of pure carbonic oxide; its fatal effects are almost always observed after absorption of a mixture of CO along with other gases, most commonly with coal gas or charcoal vapour (which is largely a mixture of CO_2 and CO), C_2H_4 (olefiant gas, heavy carburetted hydrogen), aqueous vapour, partially deoxidised air, &c. The abstraction of the CO_2 from this mixture, of which it forms a large part, does not in the least deprive it of its poisonous characters, which are therefore undoubtedly due to carbonic oxide. It is present in the vapours from blast-furnaces, along with CO_2; and fatal results have been caused by inhaling it in the vapours from smouldering ashes. In the case of ordinary illuminating gas, which is also a mixture of gases in variable proportions, the same dangerous element predominates, being present to a varying proportion (4 to 6 per cent.). The presence of the other constituents of coal gas in the inspired air of a room no doubt assists in rendering the action of the carbonic oxide more marked, and the presence of 0·53 per cent. will produce symptoms of intoxication, while 1·5 per cent. will cause the death of animals experimented on.

The so-called 'water-gas,' which has come much into use of late years, mainly for heating purposes, consists mainly of carbonic oxide and hydrogen, the former usually forming one-third by volume, or even 40 per cent. It is developed by the action of glowing carbon on superheated steam. The great danger arising from the nature of this gas, and the absence of odour to indicate its escape, have led to some strong-smelling gas, e.g., sulphuretted hydrogen, mercaptan, ethyl hydrosulphide, or pyridine, being mixed with it to serve as an indicator. Two deaths were caused at a manufactory in Leeds in 1889, owing to the escape of this gas, which was used for heating purposes, through a stopcock not being properly turned off.

When gunpowder is exploded the relative quantity of the gases found vary according to the proportion of the various constituents, and also according to the pressure. The carbon dioxide increases with the pressure, while the carbon monoxide diminishes. According to Roscoe and Schorlemmer, the proportion of CO and CO_2 present in different kinds per 100 was as follows:—

	No. 1	No. 2	No. 3	No. 4
Carbon monoxide	0·94	1·18	1·47	2·64
Carbon dioxide	20·12	22·47	21·79	17·39

Exposure to the action of gunpowder-vapour (mine gas) has been known to have fatal effects.

Carbon monoxide when inhaled may cause death by acute poisoning in from a few minutes to forty-eight hours, or it may induce chronic intoxication lasting weeks or months, when it is inhaled in small quantities for a considerable time—e.g. from charcoal fumes or coal gas. An atmosphere containing 5 to 6 per cent. of CO will kill animals, and 10 per cent. is very fatal. Its poisonous effects are increased by the presence of CO_2. An atmosphere containing only 0·5 per cent. of CO proved fatal to a dog when 5 per cent. of CO_2 was present, neither gas being present in a quantity which by itself would be fatal.

The cause of death is a true poisoning, and is not merely to be regarded as due to a deficiency of oxygen in the air. The carbonic oxide combines with the hæmoglobin of the blood. The union, however, is of such a character that the carbonic oxide can be abstracted by pumping.

The appearance of the blood in cases of poisoning by this gas is very peculiar and characteristic: it is of a bright cherry-red, and retains this colour sometimes for months. When examined by the spectroscope it shows also a characteristic reaction. Carbonic-oxide hæmoglobin shows two absorption bands between the D and E lines, and is irreducible by ammonium sulphide. This spectrum is entirely different from that of blood altered by dyspnœa, involving insufficient oxidation, with retention of carbon *dioxide*. Even in the most acute cases of dyspnœa, the two characteristic bands of oxidised hæmoglobin never disappear.

The earliest symptoms, where the patient is not acutely and suddenly poisoned, are nervous headache, giddiness, specks seen before the eyes, and sometimes hyperæsthesia of the skin; the giddiness may terminate in complete unconsciousness and anæsthesia, if the absorption of the poison be continued. Later there is nausea and vomiting. The pulse, which was at first accelerated, becomes slower, and the respiration also. Sometimes convulsions occur. Paralysis of the sphincters is observed with more serious nervous symptoms, as well as the appearance of sugar in the urine. The prognosis is doubtful; if the unconsciousness continues for some time it becomes very grave.

Difference in Symptoms of Poisoning by Carbonic Oxide and Carbon Dioxide

Carbonic Oxide.	Carbon Dioxide.
Absence of dyspnœa.	Dyspnœa.
Muscular weakness (paresis), coma slight or absent.	Muscular debility. Deep coma.
Convulsions.	
Hyperæmia of heart and brain.	
Blood, bright cherry-red.	Heart and lungs filled with dark blood.

The treatment must be directed, first, to the immediate removal of the patient from the dangerous atmosphere, and secondly, to artificial respiration, which must often be maintained for hours. Friction of the surface, and massage to encourage the circulation, and the electrical stimulation of the phrenic nerves, are rational proceedings, the faradic currents being applied. These are the essential means to be adopted, which must not be neglected for efforts to administer any of the hundred and one internal remedies which have been recommended. In grave cases it is also advisable to remove

the poisoned blood, and introduce fresh blood, or better still, a solution of salt by transfusion into the veins.

CARBON DIOXIDE (CARBONIC ACID, CO_2)

is a colourless, odourless gas, with a slightly acid taste, and is rather more than one and a half times heavier than atmospheric air (1 : 1·53). It exists in air to the extent of about 4 per 10,000 volumes. It is also produced in fermentation, in the burning of limestone, in deep wells, drains, coal mines, and other deep excavations (where it is known as *choke-damp*); even in grave-digging serious accidents have occurred; and it is evolved in great quantities in the artificial cultivation of yeast. The gases developed in the explosion of dynamite also contain CO_2 in large quantity. Pure CO_2 is irrespirable, causing spasmodic closure of the glottis; when diluted with about twice its volume of air it is respirable. The mixture of pure CO_2 with air, it must be noted, is a very different matter from a mixture with air in which the CO_2 has been developed by combustion or respiration, which implies not only production of CO_2 but abstraction of oxygen, every volume of CO_2 produced by combustion implying the abstraction of an equal volume of oxygen. In an atmosphere containing 10 per cent. of CO_2 developed by combustion, there will be 10 per cent. less oxygen, not to mention other modifications of the normal constitution atmosphere.

The exact proportion which must be present in the air to produce fatal effects is not known, and no doubt is variable, being influenced by individual circumstances, as well as—above all things—by the time during which it is inhaled, and the presence or absence of other noxious gases. No doubt a smaller quantity would produce effects culminating in death if carbon dioxide were present with other injurious gases, than if it was mixed with pure air. It may be assumed that 10 to 20 per cent. is a dangerous amount.

Carbon dioxide cannot support combustion, and respiration and life are soon extinguished where it is present in such proportion as that stated above. That CO_2 is in itself a poison and does not produce toxic symptoms merely indirectly by accumulating in the blood to the exclusion of oxygen, seems probable, though the question is still undecided.

The more prominent symptoms of its absorption are headache, noise in the ears, giddiness, after which some persons exhibit excitement, others depression, according to individuality apparently. Loss of consciousness and loss of power of movement are common symptoms in serious cases. The effects may last from a few moments to two to three days. There is nothing distinctly characteristic to be observed after death. The diagnosis can only be established with any degree of certainty from the history of the case, which, with the symptoms, usually gives sufficient indication of the nature of the mischief. The prognosis is less unfavourable than in poisoning with carbonic oxide, and is generally favourable, except in cases of acute poisoning continued for some time; in all cases the individuality, duration of exposure, proportion of gas present, &c., form essential elements in the prognosis.

The treatment is the same as for poisoning with carbonic oxide except as regards transfusion. It is very important that any collection of carbonic acid suspected at the bottom of wells, excavations, &c., should be thoroughly removed before men are allowed to venture in. To effect this evacuation is often a matter of great difficulty. Gunpowder may be exploded at the bottom, or limewater poured in, or baskets of lime suspended at the bottom, or water in the form of a spray introduced, or the gas may be set in movement by boughs, &c., being rapidly drawn up and down by means of a cord.

It is commonly supposed that where a candle will burn there cannot be present a dangerous proportion of CO_2. But this is not true. A candle will burn readily in air containing 5 to 6 per cent. per volume of CO_2, and will still continue to burn where there is 10 to 12 per cent. Even the smaller amount would soon produce serious symptoms, but the larger would ere long cause giddiness, coma, and death.

In a room, &c., where carbonic oxide has been present in a dangerous quantity, it is not safe to trust in the fact that a candle will burn as an indication that the danger has been removed, as oxycombustion may continue where life will be extinguished. Such a place should not be entered until it has been thoroughly ventilated.

COAL GAS

Coal gas is a mixture chiefly consisting of marsh gas (CH_4), hydrogen, olefiant gas (C_2H_4), carbonic oxide (CO), and impurities.

The following is given as an analysis of average coal gas when fairly purified :—

	Parkes Per cent.	Roscoe Per cent.
Hydrogen—H	40–45·58	47·60
Marsh gas (light carburetted hydrogen)—CH_4 .	35–40	41·53
Olefiant gas (heavy carburetted hydrogen)—C_2H_4	3–4	3·05
Carbon monoxide—CO	3–6·6	7·82
Carbon dioxide—CO_2	3–3·72	
Acetylene—C_2H_2	2–3	
Sulphuretted hydrogen—H_2S	0·29–1	
Nitrogen—N	2–2·5	
Sulphurous acid—SO_2	0·5–1·0	
Ammonia or ammonium sulphide—NH_3 or $(NH_4)_2S$		
Carbon bisulphide—CS_2		

The carbon dioxide may run to double or treble the amount here given, or even higher, and the marsh gas may be as high as 56 per cent., in which case the hydrogen is small. The statutory maximum of sulphur allowed is 20 grains per 100 feet, but as much as 60 grains has been found, and it is required that there shall be no sulphuretted hydrogen present.

The principal stages of the manufacture of gas are as follows. The coal is first distilled in large cast-iron or fireclay retorts, set in brickwork, which hold 2 to 3 cwt. of coal each, and are heated by coke fires from without. The charge takes from four to six hours to distil. The result of this process is the production of coke, which remains in the retorts, and various volatile products, including various gases, tar, and an ammoniacal liquor termed gas liquor. The tar and liquor are condensed in tubes six to nine inches in diameter, and are collected in reservoirs placed beneath.

At this stage the gas is very impure. Some of its constituents, ammonia and carbon dioxide, are not combustible; sulphuretted hydrogen and bisulphide of carbon have a most unpleasant smell and produce irrespirable gases when burned. To effect the removal of other impurities the gas is passed through coke scrubbers, where it deposits some of the ammonia, with some of the carbonic acid and sulphuretted hydrogen as carbonate and sulphide of ammonia.

The most important impurity to be got rid of subsequently is sulphur, which is present in all coals, but especially in inferior qualities. The combustion of sulphur evolves SO_2, the presence of which is not only dangerous in large, but is unpleasant even in very small quantities, and is most injurious to plants, and bleaches coloured objects of various kinds, tarnishes gilding, and almost

all metals. The sulphur which exists in the gas at this stage, chiefly in combination with hydrogen, ammonia, and compounds of carbon and hydrogen, is removed by treatment with lime, which also removes carbon dioxide and cyanogen, which last is generally present in small quantity. As ammonia does not combine with lime, a great quantity of this valuable material may thus be lost. As a purifying agent, that known as Laming's was long in great repute, but is now not much used. It consists of one equivalent of lime and one of ferrous chloride, to which chloride of calcium and oxide of iron are subsequently added. When impure gas is brought in contact with this, the ammonia and carbonic acid combine with the chloride of calcium to form carbonate of calcium and chloride of ammonium, whilst the sulphuretted hydrogen is resolved into sulphide of iron and sulphur by the oxide of iron.

The process of manufacture varies somewhat in different manufactories. For instance, instead of the above, the following stages and methods are sometimes employed :—

The impure gas from the retorts, after condensation in upright tubes, is passed through scrubbers consisting of coke, and next through a water scrubber in constant motion, where the ammonia is absorbed (and where the valuable ammoniacal liquor originates) ; the gas is then passed through three oxide of iron 'purifiers' in succession, in order to get rid of the sulphur. After this it is passed through lime to purify it from carbonic acid, being passed thence to the station meter, and from there to the gasometer.

The oxide of iron, after being subjected to the action of the impure gas, turns almost black in colour, which occurs when it has absorbed some 4 to 6 per cent. of sulphur. The time required for this will vary, of course, with the relative quantity of gas and oxide. In large well-managed works, when in full activity, the quantities are so balanced that the oxide is changed about every three to five days. It is then taken out, spread on the ground, and exposed to the air to be revivified, being turned over and over if necessary. This process requires, under favourable circumstances (good weather, abundant space, &c.), some two to four days. As it becomes 'revived' it gets gradually lighter in colour, turning to brown. It is then returned to the purifier for further use, and after serving its purpose there is again 'revived,' and again taken out. Ultimately, when it has taken up as much sulphur as possible, which may reach 50 to 70 per cent., it is taken to chemical works, and the sulphur it has taken up is utilised for the manufacture of sulphuric acid, if that process of utilisation is employed.

The gas-lime has a strong and offensive smell, and is not easy to dispose of. It is unsuitable as manure until after long exposure to the air ; and it must not be discharged into streams, nor buried in the earth, as it would soon pollute wells and streams, and its vapours may be carried a long way subterraneously. Salts of iron are the best means of rendering it harmless.

Laming's purifier becomes regenerated by exposure to the air, the iron becoming oxidised and the sulphur set free ; but large airy sheds are required for the purpose, and its emanation may be very offensive.

The gas is conducted from the purifiers into the gasometers, vast receptacles which are placed in excavations in the earth reaching to a great depth, and in which water is collected to seal the gasometers and prevent the escape of gas.

The employment of gas involves important sanitary considerations, which are even more important for those who have it introduced into their houses for use as an illuminating and heating agent than for the makers of it;

indeed, the workmen, as a rule, do not suffer much from the specific product they manufacture.

During the removal of the gas-lime from the tank it is liable to cause considerable irritation to the nose and eyes, through the dust and vapours of cyanogen compounds and ammonia given off. The care required to be taken in disposing of the gas-lime has already been referred to.

The construction of the underground receptacles of the gasometers requires to be of the best kind to prevent leakage, and the escape of the water, charged as it often is with tar, carbolic acid, &c., by which water-supplies, &c., may be rendered unfit for use entirely, or for very long periods. Some of these gasometers are of immense size, many holding over 8,000,000 cubic feet of gas. One to hold 12,000,000 is now being built at North Greenwich, and the depth of the excavated bed may reach to 30 to 40 feet.

It is a matter of no small importance that effective precautions be taken to prevent either the escape of gas from the pipes, as they pass underground, or the entrance of air into them; water getting into smaller pipes causes inconvenience by the flickering ('bobbing') of the light. Gas escaping through the ground may travel long distances, and enter dwelling-houses, and produce serious and even fatal effects; it may injure water-supplies, and it is very injurious to trees, the roots of which are exposed to its action; they soon shed their leaves and die.

Coal gas when mixed with air in the proportion of 1 volume to 8 to 12 is highly explosive, but even 1 volume to 6 to 7 is dangerous.

The sanitary considerations with regard to coal gas by no means terminate with the completion of its manufacture. Owing to its constant presence in the gas pipes which ramify in every direction through our houses, and often allow of escapes of gas, the most careful supervision is called for. The escape of a large quantity of gas speedily betrays itself by the smell, but small quantities may be escaping continually without producing any characteristic odour, and yet may cause very serious effects. Gas may lose its smell easily enough, even when escaping in considerable quantity, if it has to filter through even a small thickness of wall, or through the floor of an ordinary house, where the pipe lies between the floor of an upper room and the ceiling of that below. Of course the deodorisation will depend on the quantity, pressure, &c., and the speed with which it passes through the obstacles. It is generally supposed that so little as 0·5 per cent. of gas in the air of a room will produce a readily detectable smell. But in a room which is constantly occupied, where there is much furniture (which always gives off a certain amount of odour), several gas lamps (which often have more or less smell, and a very decided one if there be an india-rubber connection with the gas), a great deal more than that proportion will not attract notice, especially if the occupants of the room be inured to the presence of gas, and are thus rendered to some extent abnormally defective in sensitiveness of smell.

Among the worst of the products of combustion of coal gas are sulphuric acid, which may sometimes be tasted on the surface of objects in a room with bad gas; and carbon monoxide, of which a considerable quantity is given off when gas is only partially burned.

But it is in bedrooms that the effects of escapes of gas, often trivial and not noticed, are likely to be most harmful. During the day and evening people are more or less in movement: the doors are frequently opened and shut, the room is more or less ventilated by these means, and perhaps by the fire. But a person remains in bed usually from six to eight hours, in an atmosphere which is scarcely in movement, and is very commonly hardly ever renewed, owing to the common habit of keeping the bedroom door shut; the bed is

often intentionally placed with the head close to the gas bracket, and, as one goes to bed with the intention of sleeping, it is not noticed whether some drowsiness may not be attributable to a slight escape of gas instead of to natural causes. The writer knows of many cases of chronic illness entirely due to absorption of gas in this way, the patients recovering completely when they were removed to another bedroom where there was no escape. He was himself a great sufferer for several weeks, and quite incapacitated from work, owing to an escape of gas between the floor of his bedroom and the ceiling of the room beneath. The gas had quite lost its characteristic odour in passing through the floor and carpet, although the quantity was sufficient to make a large flame when a light was applied at the point of escape.

As an illustration of the remarkable way in which coal gas may be drawn into a house from an escape in a main outside, the following tragical history, investigated by the writer, is most instructive. It occurred in 1882 in the town of Glossop. In front of a couple of cottages in the outskirts of the town ran an iron gas-pipe, two to three inches in diameter, some eight to ten inches under the surface of the ground. This pipe had supplied a mill beyond the cottages; but the mill being disused at the time of this occurrence, the end of the pipe was plugged, but the pipe continued full of gas. The cottages were not supplied with gas. The pipe was about three yards from the front wall of the houses. A woman, her two children, and a man lived in the cottage nearest the town. As none of the inmates of this cottage were seen during the whole of one day, and no sound was heard, the neighbours (who, as the day wore on, noticed the smell of gas) forced an entrance. On getting through the front door they were almost suffocated by the smell of gas, and on making their way upstairs they found the man and the two children dead, and the woman in her last moments. It was found that the gas-pipe was broken (probably by a cart which delivered a load of coal at the house on the previous evening) underground about five yards from the dwelling-house. An outhouse built in connection with the house intervened between the broken pipe and the house. The gas, therefore, had traversed all this extent of earth, had passed through the foundation wall, and, having first narcotised the unfortunate victims, ultimately killed them.

It is a most remarkable fact that, the pipe being laid close to the surface, the gas did not all escape above ground instead of travelling so far underground into the house, the surface being only ordinary earth, hardened by traffic of feet only. There was only one fireplace in the house, and that downstairs; in the room upstairs, where the victims lay, there was none. This aspiration can only be attributed to the warmth of the house. The outside air and earth would not be very cold, as it was in summer.

It is, of course, possible that the gas may first have entered the outhouse and penetrated from thence into the dwelling house, but it seems improbable, as there was no accumulation of gas noticed in it.

Biefel and Poleck give the following analyses of coal gas, before and after passage through a layer of sandy-humus earth two metres thick (= 78·7 in.):

	Before passing through the 2 metres of earth	After passing through the 2 metres of earth
Carbonic oxide—CO	10·52	13·93
Carbon dioxide—CO_2	3·06	2·23
Heavy carburetted hydrogen—C_2H_4	4·66	0·69
Light carburetted hydrogen—CH_4	31·24	17·76
Hydrogen—H	49·44	47·13
Oxygen—O	0·0	6·55
Nitrogen—N	1·08	11·71
	100·00	100·00

IODINE

Dried sea-weed is collected in piles on the shore and burned, leaving an impure ash known as kelp, which contains iodine. Subsequently the iodine is obtained pure by heating with sulphuric acid and manganese dioxide and afterwards subliming. It gives off a perceptible vapour at the ordinary temperature. Considerable quantities of metallic compounds of iodine are found in the preparation of nitrate of potassium from Chili nitrate.

In Germany iodine is chiefly got from the iodide by distillation with concentrated sulphuric acid and nitrate of potassium.

Iodine acts as a caustic on the skin. The vapour when inhaled in any quantity produces irritation of the respiratory passages, coryza, sneezing, frontal headache, and even temporary unconsciousness. Prolonged exposure to its action causes a characteristic coryza, with exaggeration and persistence of the symptoms which are observed in temporary attacks.

The distillation and subsequent sublimation of the iodine are the stages at which the vapours are likely to be most dangerous, and the essential precautions are to have the vessels made thoroughly air-tight, so as to secure the cooling and condensation of the iodine without escape of the vapour. When the iodine is being removed from the receptacles it is also liable to affect the workpeople. In addition to other precautions it is then necessary to be careful about the local action of iodine on the skin, especially if this be broken. When sulphuric acid is added to the kelp, in the early stage of the manufacture, large volumes of sulphuretted hydrogen are set free which should be drawn into the chimney, if the process is carried on in a factory, and not in the open air.

BROMINE

Bromine is found as bromides in many mineral springs, in sea water, and in the ash of marine animals and plants (kelp). The mother liquor obtained by evaporation, or by treatment of kelp, &c., is distilled in stone vessels with manganese dioxide and sulphuric acid. The bromine evolved is condensed in a leaden or earthenware tube, and collected in bottles.

The impure bromine is purified by fractional distillation. It is kept in bottles with well-ground stoppers, fixed with varnish, clay, and linen or parchment paper. In consequence of its dangerous properties, and the consequent expense of transport, bromide of iron is often used for transport instead of bromine, for the preparation of the various salts in use, of which enormous quantities are now used in medicine.

Bromine is a dark, reddish black, heavy liquid. It has a strong, peculiar, irritating smell, and acts as a strong poison when inhaled. It affects the workpeople very much like iodine. It causes irritation of the mucous membrane, increased flow of saliva and tears, cough, malaise, giddiness, spasm of the glottis, and asphyxia. Immediate removal from the place and inhalation of aqueous vapour are recommended as the best remedies. Free ventilation to prevent the accumulation of the poisonous vapours is very important.

The most dangerous stages of the manufacture are when the stone receptacles are being emptied. In the emptying of the vessels used for rectifying the bromine, also, the workmen are much exposed to danger, and must protect mouth and nose with cloths. Again, when the bromine is being filled into the bottles for storage, it is absolutely necessary for the men to protect their respiratory organs by the use of cloths, cotton wool, &c.

Sometimes a condition much resembling bronchial asthma occurs to workmen, but specific chronic intoxication is unknown.

It is essential that only healthy workmen should be employed in this trade. Those with any predisposition to pulmonary disease or to excess in drink should be rigidly excluded. If this be done, and the precautions referred to observed, the health of the workpeople seems not to be injuriously affected.

The passage of water containing bromine from the works into neighbouring streams and water-supplies must be most carefully prevented; the vegetation of the neighbourhood will certainly be destroyed if the vapours are allowed to escape unchecked.

CHLORINE

The effects of chlorine and hypochlorous acid are somewhat similar to those of iodine and bromine, and are frequently seen in workers where chlorinated lime ('bleach') is used, as in the manufacture of this compound, bleach works; &c.

Chlorine when inhaled in a concentrated form causes spasm of the glottis; when more dilute, irritation of the bronchial passages, eyes, nose, and throat. Men, however, soon became habituated to the inhalation of dilute chlorine, though they suffer from dyspepsia and acidity of the stomach, and lose flesh and become anæmic. Loss of smell is a common chlorine symptom among workers in chlorine.

ARSENIC

This metal sometimes occurs free in nature, but is more commonly found in combination as an alloy, especially with iron, cobalt, and nickel. It is widely distributed, and is a not uncommon constituent of mineral springs.

It is generally recovered from its ores by roasting, or by being exposed to a current of heated air in a reverberatory furnace, arsenious acid (As_2O_3) being formed. This is carried off as a vapour into long flues, where it is precipitated as 'white arsenic,' or arsenious acid.

Metallic arsenic is little used, except in the manufacture of shot to impart hardness. It also exists in 'white copper,' or 'new silver,' an alloy of copper and zinc.

The emptying of the flues or chambers in which the arsenious acid has condensed is a very dangerous operation for the workmen. They are generally cased in leather, glazed eye-holes being left to enable them to see, the mouth and nose being covered with damp cloth.

Combined with copper it constitutes the brilliant Scheele's green, and another much used pigment, the Schweinfurth green, is a double salt of arsenite and acetate of copper. These are the only metallic arsenites used in the industries. They are found in wall papers, green water-colour paints, oil paints, wafers, &c., and have caused fatal effects from being inadvertently used to colour blanc-mange and confectionery. The makers of the arsenical green wall paper, printers using green pigment, and occupants of rooms papered with this deadly substance have suffered serious illness and even died from its effects. It is also used in preparing animal skins for stuffing. Schweinfurth green is used for colouring carpets, artificial flowers, light tarlatan for dresses, green paper lamp-shades, &c. The grinding of Schweinfurth green is a most dangerous process, and yet it is very remarkable that the men suffer so little, seeing that they are covered with the dust from head to foot.

In the preparation of artificial flowers (leaves, buds, twigs, &c.) the green

colour is obtained from the same source. The leaves are cut out of paper, cloth, &c., which is usually dyed beforehand with a colour of the same character, then they are usually varnished and the powdered Schweinfurth green sprinkled on. This is a most dangerous operation, leading to inflammation of the eyes, swelling of the face, and ulceration of the hands. The use of the dry powder should be entirely forbidden, and the colour should be used only when mixed with collodion, turpentine, &c.

Arsenite of potassium is an important compound, as it is used for the manufacture of Scheele's green, which is an arsenite of copper. It is produced by acting on a solution of sulphate of copper with arsenite of potassium, or by dissolving in water arsenious acid or adding sulphate of copper, and then precipitating with an alkaline carbonate.

Arseniate of sodium is also of importance, because in its manufacture, as in that of arsenic acid, abundant and highly dangerous nitrous vapours are discharged.

Arsenic acid is largely used in various industries, especially in the manufacture of certain aniline colours such as magenta and rosaniline. Arsenious acid has been found, and arsenic acid been found to the extent of 7 per cent. in such colours. These brilliant colours are largely used to render more attractive syrups, sweetmeats, liqueurs, &c. It has been supposed that the bad effects sometimes attributed to the wearing of flannel, socks, &c., dyed with aniline colours may really have been due to arsenic present in some form.

Orpiment, or yellow tersulphide of arsenic, owes its dangerous properties to the presence of arsenious acid. It is sometimes found native. It is the chief ingredient in King's yellow, which is a mixture of orpiment and arsenious acid. It is much used in paper-staining, painting, dyeing, and colouring toys. It has been used (instead of lead chromate) to colour Bath buns. It is also used in fellmongering, mixed with lime, in the removal of wool from the hides.

Absorption of the poison may take place through a raw surface, and even through the unwounded skin. It is not an accumulative poison, but is eliminated by the urine, sweat, and bile. It causes paralysis of the heart, but whether directly or indirectly is uncertain.

The conditions of chronic poisoning may ensue from one large dose, or from repeated small doses. Gastric catarrh is the prominent symptom at first, accompanied by the peculiar feeling of burning in the fauces, dry tongue, thirst, and sometimes superficial ulceration in the mouth. There is irritation of the conjunctivæ, with suffusion of the eyes, and more or less photophobia. The skin often exhibits a peculiar vesicular eruption, called eczema arsenicale, or the eruption may resemble the nettle-rash form of scarlatinal rash. There may be well-marked nervous symptoms, even including paralysis.

Notwithstanding these severe symptoms of general intoxication patients have been known to recover completely, after two to three weeks, if placed under proper treatment.

It is absolutely necessary to remove from the influence of the poison persons who show symptoms of being affected, and this whether they are suffering from symptoms of general intoxication, or merely from skin or other external affection. It is by no means certain that the skin affections are not sometimes indicative of antecedent general affection, and not merely a preliminary and localised result of the action of arsenic.

The personal hygiene of the workmen should be directed to the maintenance of great personal cleanliness, avoidance of exposure of any wounded

surface of skin to the action of dust or vapour containing arsenic, avoidance of taking any food or drink in the workrooms, regularly changing the working clothes before going home, shaving the face clean and keeping the hair short to avoid accumulation of dust, &c.

The preventive hygiene consists partly in the provision of suitable condensing chambers, and especially their complete closure, and partly in efficient ventilation.

Public hygiene demands the absolute prevention of any water containing arsenic being discharged into sewers or streams. The chimneys should also be of considerable height, and from time to time the vapours should be examined to see that no arsenic is escaping. The insertion of numerous projecting buttresses in the condensing flues is a successful method of increasing their power of securing the maximum of condensation.

One of the most important of the measures of precaution is the employment of arsenical colours as little as possible, and it is greatly to be desired that chemists would direct their attention to enabling this to be done successfully. There can be little doubt that all the advantages of the highly dangerous arsenical greens could be obtained without their dangerous properties, if the question were seriously taken in hand and an effort made to release the makers and men from the danger they involve.

CHROMIUM

Although this metal is scantily distributed in nature, its compounds are greatly used in certain industries, and have a great sanitary importance from their dangerous action. The principal ore of chromium is chrome ironstone.

Its most important salts for industrial purposes are the bichromate ($K_2Cr_2O_7$), which is prepared by fusing a chromic compound with potassium carbonate, when it becomes oxidised and a yellow soluble chromate is formed. By the addition of sulphuric acid the bichromate is formed, in red crystals. This salt is the great source of the valuable chrome pigments, and is used by both the calico dyer and calico printer to produce the chromates of lead (chrome yellow and orange red). It is also used in mordanting wool and in the dyeing of silk and linen. Chrome colours are also largely used in glass and porcelain painting.

It is equally important to the dyer as a powerful oxidising agent, this property being sometimes utilised to develop colour, and sometimes, on the contrary, to destroy it.

Chromates of barium, lead, and copper, and a dichromate of sodium, chrome alum, chromium sulphate and acetate, and several other compounds, of which the nitrate, sulphate and nitrate-acetate, and acetate are the most important, are much used in calico-printing for steam-colours—e.g. browns, blacks, olives, &c.

Poisoning from swallowing of bichromate of potash has occurred, the principal symptoms resembling those of Asiatic cholera very closely: about half a grain has been known to produce poisonous effects, with vomiting, and profuse diarrhœa. The symptoms are not unlike those of poisoning with arsenic or mercury. Sometimes, however, the nervous system alone seems affected, and not the digestive tract. Poisoning has been caused by the use of chromate of lead instead of turmeric for staining the skins of sausages.

Chrome yellow is frequently used to colour papers for wrapping bonbons in; it is more likely to be dangerous in the form of paint in children's paint-boxes, and has more than once caused death when employed to colour sweets in quantities so small as a fifth of a grain.

The action of the chromates and bichromate of potash on the skin and nerves causes destructive ulcerative action on the skin and mucous membranes, unfortunately too well known. It has been said that a man who worked at bichromate could be recognised at a glance by the deformity of his nose.

The pulverising of the chrome-iron ore does not appear to produce the almost specific injuries of chrome, and is offensive only as a dust, which, like others, is injurious when constantly inhaled.

Danger arises when the chromates are being ground. The fine dust falls on the skin and adheres to moist parts, which it irritates, acting with greatest severity on the delicate mucous membrane of the nose, where the carelessness of the workmen often leaves the dust undisturbed. There is often a quantity of caustic alkali mixed with the chromate, which increases the effect of the latter. The inhaled dust causes sneezing, and a thickish watery or bloody discharge from the nose. Ulcers form on the septum, and not infrequently end in perforation, which is most commonly preceded by the formation of a scab. There is seldom any offensive odour from the ulcers. On the skin also the vesicles or papules caused at first by the irritation may end in ulcers having clean-cut edges, and appearing as if punched out. They may extend over a large part of the body, and destroy the tissues to the bone if neglected. It is said that snuff-takers enjoy immunity from these effects. The operation of pulverising the bichromate and other dangerous salts should be done in a closed chamber, and should be effected by rollers. (Cf. Sanitary Precautions, art. LEAD, p. 964).

The chimney of the calcining ovens must be furnished with proper means of drawing off the dust and fumes into a suitable chamber, to prevent destruction of the vegetation around, and injury to men and animals. There is also danger of ponds and rain water being poisoned. It is most important that wash water, &c., which may contain bichromate, be not discharged into streams or ponds used for drinking. So dangerous is this process that it should not be tolerated in thickly populated neighbourhoods.

MERCURY

This important article of commerce is found native in but small quantities, and is chiefly met with as the sulphide or cinnabar (vermilion), sometimes calomel or subchloride. It is the only metal which is liquid at the ordinary temperature, and is so volatile that it gives off vapour at all temperatures.

The metal may be extracted from the native cinnabar by burning off the sulphur, or by heating the ore with some substance which will combine with the sulphur, and form a fixed compound with it, thus allowing the mercury to be separated by heat. The former method is practised at Almeida, but owing to defective condensation is extravagant. The latter method is effected by mixing the cinnabar with iron filings or slacked lime, and distilling in retorts. The sulphur of the cinnabar combines with the iron or lime, and the mercury is vaporised and condensed in receivers filled with water.

Mercury is used in great quantities in extracting gold and silver from their ores by amalgamation, and these amalgams are largely used in silvering and gilding. It is also used largely for silvering mirrors, for the preparation of vermilion (cinnabar), a most important and durable pigment; as well as in the construction of philosophical instruments, and as a medicine. Cinnabar is very largely used as a pigment.

The perchloride (corrosive sublimate, mercuric chloride, $HgCl_2$) has come into great use of recent years as a disinfectant. It exercises a most destructive action on micro-organisms. A solution of 1 per 1,000 is sufficiently strong

for almost any purpose of this kind. Mercurial poisoning has followed the use of such solutions as this.

Mercurous chloride (calomel) is usually prepared by heating finely divided metallic mercury with corrosive sublimate.

Among the trades in which mercury or its preparations are used, and in which danger arises to the workpeople, may be mentioned the following :—

Bronzing : not infrequently plaster objects are given a metallic appearance by rubbing them with an amalgam consisting of equal parts of mercury, tin, and bismuth, and subsequently varnishing them. Persons engaged at this work not infrequently exhibit the symptoms of mercurial poisoning in a very intense degree.

Hat-making is a trade of a still more dangerous character. In the preparation of the skins it is a common practice to rub them with a coarse brush, wet with a 10 to 11 per cent. solution of acid nitrate of mercury in nitric acid.

In the subsequent operations of depilation and shaking the skins, clouds of mercurial dust, as well as that of arsenic, are spread about, to the great danger of the workpeople, among whom poisoning with both these metals is common.

Gilding by the aid of mercurial gold amalgam is also a dangerous occupation, the workpeople being liable to intoxication at various stages, chiefly in the preparation of the amalgam, and in its application to the objects to be gilded. Mercurial vapours are developed in the bath, and also when the mercury is volatilised at the moment of applying the gilding; further, the continued handling of the mercurial amalgam itself leads to cutaneous absorption and intoxication.

The emaciated, unhealthy appearance of the workmen too commonly indicates the nature of their occupation. Closer examination shows their irritated gums, often toothless, and the existence of skin irritation, dyspnœa, and other disorders arising from exposure, not only to the dangerous action of mercury, but also to the nitrous fumes, which are so disastrous to those engaged in this trade.

Artificial flower-makers are exposed not only to dangers from the use of poisonous arsenical and lead colours, but are obliged also to use the no less dangerous mercurial pigments, chiefly the sulphide, chromate, and biniodide (brilliant scarlet).

The operations of preserving and stuffing the skins of animals is dangerous to those employed, from the fact that arsenic (generally in the form of soap) and corrosive sublimate are largely employed by them. It is not merely at the times when the preservative materials are employed that the danger exists, but long afterwards; when these materials have become desiccated they are converted into dust, which permeates the atmosphere of the rooms where the stuffed animals are kept, and may cause all the symptoms of arsenical or mercurial poisoning.

Photographers, who employ the bichloride, are also liable to absorption of the poison, especially if there should be any fissures or wounds on the hands. The large amount of mercury employed in telegraph offices, where the wire connections are often made by means of cups filled with mercury; the enormous area of zinc plates which have to be kept amalgamated with mercury at large telegraph stations; the risks connected with the preparation of barometers and thermometers, from which the boiling mercury sometimes escapes, suggest important points for sanitary supervision.

The liability to mercurial poisoning is all the greater, as it is a metal which can undoubtedly be absorbed through the unbroken skin. This fact is familiar from the readiness with which toxic effects are produced by inunction of

mercurial ointment in medical practice. It may also be absorbed through the lungs, whether it enter in the form of vapour or dust, as well as from the digestive tract.

The absorbed mercury probably exists chemically combined chiefly with albumen; but, as it may be excreted with urine free from albumen, it is manifest that the albuminous compounds may again undergo decomposition. Mercury is excreted not only by the kidneys, but also in the bile, milk, fæces, and probably in the sweat.

It is remarkable that mercury may exist in a latent form in the body, and under favourable conditions become active and produce serious symptoms in persons who had for years been apparently free from its influence.

The predisposition to mercurialism varies greatly in different persons, of which Alfinger observed an illustration in the case of the sister of a woman engaged in 'silvering' mirrors, who, although she had never been in the factory, became affected with mercurial stomatitis through contact with her sister, who was engaged in the mercurial work, but who was not herself in any way troubled. The injurious effects are usually observed within a few weeks or months after exposure, while some persons will escape for months, or even years.

The earliest symptoms are nearly always increased secretion of saliva and irritation of the mucous membrane of the mouth, accompanied soon by a peculiar metallic taste. Inflammation of the gums soon follows: they become, swollen, tender and disposed to bleed, and the breath becomes most offensive. The morbid condition soon spreads over the cheeks, lips, and tongue, and they become covered with a greyish, croup-like membrane. At points where the teeth press, ulcers are commonly observed, which may extend in depth and area, and lead to extensive destruction of tissue. The general health is always involved at this stage, and there are fever and restlessness, with gastric and intestinal derangement. In some cases the nervous phenomena precede and are much more serious than the local. The patient suffers from great anxiety, the least thing unnerves him, and he may have hallucinations. He cannot eat, suffers from considerable salivation, and loses flesh rapidly.

The gravity of these cases often leads to long illness, lasting four to six weeks, and may even lead to chronic mercurialism lasting for years; but they seldom end fatally. The inflammation of the mouth, where the general health has not suffered much, is usually subdued in a few days.

If these symptoms be disregarded, and the patient be not at once removed from exposure and put under proper treatment, there are superadded other more serious troubles. There comes on gradually a trembling of the muscles, commonly known as 'the trembles' (mercurial tremor), affecting gradually a larger and larger area of the voluntary muscles, until finally the patient may be deprived, not only of the power of locomotion, but his speech becomes stammering and hesitating (psellismus mercurialis), and he may be quite unable to feed himself. The 'trembles' commence usually in the face and tongue, and gradually extend to the arms and legs. At first the muscles are only affected temporarily, mostly during movement or under emotion, and the tremor may cease entirely during sleep. Reflex action and power over the sphincters and electrical irritability continue unimpaired. These symptoms may progress and be rendered more serious by the occurrence of mental derangement, which sometimes takes the form of maniacal excitement, but more usually of hypochondria.

The prognosis is in general favourable, but sometimes the tremor is never lost.

Complete removal from risk of further absorption, good food and air combined with ferruginous tonics, are the best treament. Chlorate of potash is very useful for the stomatitis. Small doses of iodide of potash no doubt increase elimination. Large doses have been known to increase the severity of the symptoms, apparently by setting free mercury fixed in the tissues, and thus leading to its entrance into the blood and nervous tissues.

Sanitary Precautions.—In this as in other dangerous trades it is above all things important to instruct the workmen thoroughly in the nature of the risks they have to incur, and the means of avoiding them. The protection of the workman from the local and general affections arising from the absorption of mercury into the body, or from its local action, requires a combination of precautions on the part of the manufacturer in the construction and maintenance of his works, and on the part of the workman in seeing that the various means provided for protecting him are kept in good working order, as well as in taking great care to supplement these precautions by attention to personal hygiene.

In the removal of the contents of the condensing chambers and flues the greatest care is required, and these must be constructed so as to prevent the escape of fumes or gases. The men should be provided with long overalls accurately fitting at the neck and wrists, so as to keep the skin as well protected as possible, and the hair of the head and face should be kept close cut, and a cap of paper or other smooth material always worn, to prevent deposition of dust in them. A good mask would be a great boon, but is still a desideratum. The clothes used in the works should not be worn at home, but left at the workshop. Great cleanliness should be maintained by frequent washing, especially of the hands, face, and mouth; and means for this should be conveniently placed for the workmen, as well as warm baths, in which their whole body can be thoroughly freed from the noxious materials. The chambers where mirrors are 'silvered' require to be well ventilated, and the ventilation should be downwards, as the vapours are heavy and rise but slowly from the mercury bath, and all the workrooms must be freed from deposits of dust at very short intervals. In spreading the mercury on the glass it is most important that the hand be not directly placed in the metal; the flannel with which the spreading is usually done should be held by a rod, so as to keep the workman as far as possible from the fumes. The mercury should be kept in covered vessels as much as possible, to prevent the diffusion of the vapour which it gives off at all ordinary temperatures, and still more in hot workshops. All cloths, &c., after use should be removed as rapidly as possible from the workshop, to avoid exhalation from them.

There is one other means of general and great importance for purifying the air of the rooms, viz. the diffusion of the vapours of ammonia throughout them. This cannot be properly done while the men are in the workshops, but at night when they have left it should be done freely. The very best results are said to have been obtained from this practice, which has long been in operation; but the *rationale* of it is not apparent, as metallic mercury does not combine with ammonia. In the works at Chauny this process has been employed for over twenty years with the best effects, as is alleged.

As there is always danger from the mercury which gets spilled on the floor during the various processes in which it is used, the floors should be made of good asphalte to prevent its absorption; and by keeping the floor wet the mercury is rendered more easily visible. By giving the floor an incline, and having gutters constructed, the collection of the mercury is greatly facilitated. It will also be found a great advantage to have in the workshops, on the floors

and elsewhere, quantities of tinfoil, or other metal which readily forms an amalgam with mercury, as then the danger will be mitigated, and pecuniary loss by waste of the metal greatly diminished.

LEAD

This metal is a most important article of commerce, and is used in a great variety of industries. The specific and peculiar character of the symptoms produced by intoxication with lead, and the fatal results which sometimes follow, combined with the epidemic occurrences of lead-poisoning from drinking water, have attracted a great deal of attention to the subject, and still there is much which is mysterious and quite unknown in connection with the familiar diseased condition arising from absorption of lead.

It may be introduced into the system either by direct absorption through the skin or mucous membranes, or by the inhalation of the vapour or powder of lead or its compounds, which, produced in certain stages of its manufacture, or by the extraordinary variety of uses to which compounds of lead are put, account for the frequently surprising and apparently unaccountable occurrences of symptoms of plumbism under circumstances which at first sight would seem to exclude the possibility of such.

Among the workmen who are most exposed to the danger of lead-poisoning may be mentioned, besides the lead workers proper, the following: painters, gilders, file-cutters, type and note founders, calico printers, colour grinders, glass grinders, bronzers, enamellers, &c.

The industries in which lead is used are too numerous to mention. Architects and builders use it for gutters, roofs, windows, &c.; it is used for gas and water pipes; in chemical works for linings for sulphuric acid chambers, pans, and cisterns; tea-chests are lined with it; in combination with tin, bismuth, and antimony, it forms soft solder; while white metal and brass both contain it; printer's type, stereotype metal, organ pipes, and a host of other articles are formed of material containing lead.

Chemical compounds of the metal are used as colouring agents, white, red, and yellow lead being enormously used; white paint and white papers most commonly have lead for the foundation of the colour.

Carbonate of lead, or white lead, is very extensively used as a paint, and is manufactured on an immense scale. It is prepared by various processes: (1) By the Dutch method it is obtained through the action of a weak solution of vinegar on coils of thin sheet-lead. The grinding of this carbonate, even when done under water, is very dangerous to the workmen. (2) By Thénard's method it is developed directly by the action of a current of CO_2 on the lead. (3) The CO_2 given off in the combustion of coke has been employed at Birmingham for the same purpose. The carbonate should always be sent out as a moist substance.

White lead, or carbonate of lead, $PbCO_3$, so largely used as a pigment, is still mostly made by the old and dangerous Dutch process, which may be thus briefly described. On the tops of small earthenware pots, containing acetic acid, thin sheet-lead is placed, and the pots are ranged in layers of tan, which by its oxidation maintains sufficient heat to keep the pots at a moderately warm temperature. A layer of wooden planks is placed over the whole; then another layer of pots, and so on in successive layers till a 'stack' of 'blue beds' is formed. No special danger is incurred in the stacking of a blue bed. The acetic acid is slowly volatilised by the heat evolved by the oxidising tan; the lead is oxidised, combining with the acid to form subacetate of lead, which is again decomposed by the carbon dioxide

evolved from the tan, subcarbonate of lead (carbonate of lead or white lead) being formed; and in this way the whole of the lead is gradually converted into a crust of white lead. The stack is then, after the lapse of about three months, converted into a stack of 'white beds'—i.e. of white lead. When the conversion is complete, girls enter the stack, place the white lead in trays, and carry these chiefly on their heads, first to rolling mills, where the crust is removed from any undecomposed lead, and subsequently to heated drying stoves, kept at a temperature of about 200° F. After being dried, the white lead is ground, washed, and then dried as a fine powder. The commercial value of the product greatly depends upon its minute state of division, white lead being one of the most minutely divided of known mineral substances. This minuteness of its particles greatly favours the dissemination of white lead as dust through the atmosphere, and aids its absorption when it comes in contact with any absorbing surface of the body. It is the women engaged in removing the white beds, and in the stoving, grinding, and packing operations who are the greatest, though by no means the only, sufferers from plumbism.

The effects of working in white-lead factories are insidious, though in the end severe, and not infrequently fatal. They are collectively the now well-recognised symptoms of plumbism or saturnine poisoning: colic, constipation, irregular and profuse menstruation, wrist-drop, and other forms of paralysis; pains in the joints, often termed 'rheumatics,' cachexia; degeneration of the liver and kidneys; and by no means unfrequently epileptiform convulsions, ending in coma, precede a fatal termination of the disease. Throughout there usually is the well-known and characteristic blue line of lead-poisoning along the free margin of the gums, due to a deposit of sulphide of lead.

The varnishing of leather is commonly effected by the use of red and white lead; what is termed 'glacé' leather for gloves and the beautiful glaze of visiting and playing cards contain the same deadly ingredient.

The beautiful lustrous leaves and flowers which represent the sparkling dew are poisoned with lead, and some of the most lovely artificial flowers are dyed with it (the white with carbonate of lead, the red with red lead, the yellow with chromate of lead).

Artificial jewels mostly contain the same ingredient and are prepared with great danger to the workpeople; and the glaze of the commoner saucepans also contains it. A poisonous varnish containing litharge is used by gilders of wood.

Dressmakers have been poisoned by using silk weighted with acetate of lead (sugar of lead), through moistening the ends to facilitate threading their needles; and tailors have had the same fate from the lead employed in dyeing the alpaca they were working on. Even the preparations of lace and straw hats are commonly associated with this agent. Painters are notorious sufferers, several of their colours containing lead, and white paint containing little else than the carbonate.

Acetate of lead, or sugar of lead, sometimes particularised as 'white,' is prepared by dissolving litharge in acetic acid, and evaporating to crystallisation. The name sugar of lead is no doubt due to its appearance and sweet taste. There is a 'brown sugar of lead,' also prepared in a similar way by the substitution of crude acetic or pyroligneous acid for the purer acetic acid. This salt is used in dyeing and printing, and formerly (not so much now) for weighting silk. In dyeing it is largely used for producing chrome yellow and chrome orange, and also in the manufacture of the acetates of aluminium, iron, and chromium. It is also used in making hair-dyes.

Nitrate of lead is prepared by dissolving litharge in hot dilute nitric acid. Both the acetate and the nitrate are used in calico-printing and cotton-dyeing for the production of orange and yellow colours. In the latter operation, after the cotton has been printed or impregnated with a solution of the lead salt, it is passed through a solution of bichromate of potash. In calico-printing the lead may be fixed as sulphate by means of sulphate of soda. In these cases the lead acts as a mordant, the colouring matter being the chromic acid or bichromate of potash.

Sulphide of lead, or galena, occurs in nature, and is used mainly for glazing pottery, bricks, &c. Not only the producers of these articles, but the users of them, may be infected by the presence of lead in the glaze.

Lead is readily acted on by air, the brilliant metallic lustre left on section becoming tarnished by formation of a thin film of oxide on the surface. Air contained in water also acts powerfully on lead, while water deprived of air will not tarnish lead placed in it, for an immensely long time. When lead is placed in well-aërated water, the film of oxide formed on its surface is quickly dissolved by the water.

Shot is made from molten lead, which is allowed to fall a considerable height (in so-called shot-towers) into water. It is, however, not pure lead which hardens it, but an alloy of lead and arsenic, the proportion of arsenic being about three to seven per 1,000.

Notwithstanding the numerous opportunities presented of seeing lead-poisoning, the exact nature of the disease is still far from being thoroughly understood. That a general cachectic condition exists in persons long subjected to the action of the poison is clear; but there is a great difference of opinion as to whether the blood, or some special organ, is chiefly affected. Henle considers that absorbed lead acts mainly on unstriped muscular fibre, while the more common view perhaps is that the nervous system is the special seat of attack.

The danger of infection among workmen much exposed to the inhalation of the fumes of the metal, or to dust which contains it, or to absorption through the skin or digestive tract, is very great. When the symptoms appear they are found to be, although multiform, still distinctly uniform, so far as each group is concerned, and characteristic. Even before decided symptoms show themselves, the patient, by his 'facies' and general condition, betrays the approaching outbreak of disease. This preliminary condition may last a considerable time. There is usually loss of flesh and loss of strength and weight; the face, and even the whole skin, assumes a peculiar yellowish-grey colour (not unlike that of long-term prisoners), the breath becomes unpleasant to smell, there is a peculiar dry sweetish flavour in the mouth, and the very characteristic blueish-grey line appears on the gums.

The blue lead-line on the gums may exist, the whole gums being even black for years, without any symptom of lead-poisoning, and it may be absent when the symptoms are well marked. It is probably much more frequently a local deposit than a result of elimination of lead from the system. Microscopic examination of the parts shows black granules, situated some inside and some outside the capillaries, and probably consisting of insoluble sulphide of lead. The sulphur is supplied probably from decaying organic remains of the food deposited between the teeth, &c.

It is most commonly the abdominal organs which first exhibit decided symptoms of the disease. After a gradually increasing condition of constipation, the patient begins to complain of more malaise than is usually attributed to that cause, with a feeling of tightness in the belly, which is hard and retracted. This sensation becomes usually a more or less severe colicky pain situated

about the umbilicus, and radiating chiefly downwards, and having the peculiarity of being relieved by pressure. The stomach is disordered, and vomiting frequently occurs. The pains extend to the joints and muscles, and the latter may exhibit already at this stage symptoms of paralysis, and the urine and salivary secretions are both scanty.

The remarkably slow pulse, with proportionately increased frequency of the respiration, have been dwelt on as almost pathognomonic; thirty contractions of the heart per minute with forty and more inspirations being common enough.

Where the patient is obliged to continue exposed to the accumulative action of the poison, convulsions and paralysis, the latter as a common occurrence, ensue. The muscles attacked are usually those of the upper extremities, and more particularly the extensors of one or both arms. The supinator longus and the deltoid are apparently very rarely attacked. The sensibility of the affected parts is generally left unimpaired. Along with power of contractility the muscles are found to have lost their electrical irritability, and gradually become wasted and atrophied. As a rule, the paralysis is limited to the muscles supplied by the musculospiral nerve, especially those supplied by its posterior interosseous branch.

The legs are sometimes attacked, and, curiously enough, it is the homologous muscles to those in the arm, the extensors of the leg and foot, which are mostly affected.

The appearance of the hands in paralysis is peculiar and characteristic, and is well expressed by the popular term 'drop-wrist'—'*main en griffe*.'

Secondary misshapements and even dislocations may occur, and mask the simple and characteristic appearances usually seen.

More serious consequences still may arise in the shape of pronounced brain symptoms (encephalopathia saturnina), causing usually considerable loss of sensation; there may be even complete hemianæsthesia, without much loss of motor power. Delirium, convulsions, and coma may also occur. Abortion is sometimes produced in severe cases. Dr. Rayner reports that the proportion of painters, plumbers, and glaziers among his insane patients was nearly one-third more than among the general population.[1]

It will be seen that the severity of the disease is sufficient to demand the most careful means for its prevention. The attacks may be fatal, or may, while yielding to treatment, leave permanent ill-health, and more or less deformity and paralysis behind.

From the great variety of uses to which lead in one form or another is put, it will not be surprising that lead-poisoning is found occurring under most various conditions and where least suspected. At one time it was so prevalent in Poitou, owing to its addition to inferior wines, that it was termed the *Mal de Poitou*; it was very common once in Devonshire, owing to the use of lead in the vessels used for cider-making; and the leaden 'worms' used in the distillation of rum in the West Indies caused it to be prevalent there.

It occurs among cabinet-makers from the use of glass-paper, the lead in the fine glass dust becoming dissolved in the sweat of the hand and absorbed, and the dust being also inhaled. A liquid containing as much as 45 per cent. of lead is also used for colouring wood, and has been known to cause poisoning.

The glaze of tiles, bricks, and pots has also produced poisoning, generally consisting as it does of a large proportion of sulphate of lead, as much as equal parts of this salt and ground sand being sometimes used. In this case,

[1] Journal of Mental Science, No. CXIV., New Series, No. 78, p. 223.

too, there is danger from the inhalation of the dust arising in the grinding process as well as from the fumes produced during the baking.

The makers of pottery and faïence are exposed to great dangers through the poisonous enamels they use. One brown enamel contains 52 per cent. of red lead, and a white one 2 parts of red lead, with 44 parts of calcine (which itself contains 77 per cent. of lead).

The dangers chiefly arise during (1) the powdering of these ingredients (inhalation and cuticular absorption), (2) while the workmen are dipping the vessels in the water to which the powders have been added (cuticular absorption), (3) when they are being burned (inhalation of fumes, and absorption through skin), (4) during a process sometimes employed of dusting the vessels with powdered red lead.

Every form of enamel contains lead, chiefly as oxide, combined with more or less ground flint; a white enamel contains 50 per cent. white lead.

In jewellers' workshops, in order to recover every particle of the precious metals, the sweepings are collected, and after the formation of an amalgam with the ash, an alloy of lead is made, the mercury being driven off. In this process lead-poisoning may occur.

Among the other more important trades in which danger from lead-poisoning is liable to arise, omitting the manufacture of the various lead compounds already named, the following deserve attention:

1. File-cutting. The plain bar of soft iron which is to be made into a file is placed on a flat piece of lead, as a substance to which it will adhere slightly without slipping, and which from its softness does not cause much jarring when struck. The teeth of the file are cut by a sort of blunt chisel, held in one hand, which is struck with a hammer held in the other. Some fifty or sixty such strokes or more will be given in a minute, and each stroke cuts a tooth in the file. It is evident that the hands of the file-cutter are almost constantly in contact with the leaden bed of the file; and more important, perhaps, when one side has been cut, and this rough side is turned down on the lead, there is a good deal of rubbing away of the lead by the teeth of the file.

All the larger files are cut by men, while of the small ones a large number are cut by women.

The cutters' hands are invariably covered with dirt, and under the nails there is a considerable quantity collected, in which metallic particles, both of iron and lead, can readily be detected by a magnifying glass or even by the unaided eye. The rough benches or tables at which they work also show dust in considerable quantities, of which a large part is lead.

The sweat of the hands, &c., undoubtedly oxidises and dissolves the lead, and absorption then readily takes place.

2. The glass-cutter, who executes his often highly artistic work with the simplest apparatus, sits or stands in front of a revolving grindstone, usually some 8 to 10 inches in diameter, and of various thicknesses (from about 1 inch to 2·3 inches usually). The lower part of the stone is within a trough, into which the water constantly supplied from above falls, as well as the fine particles ground off the glass. The article to be 'cut' is held against the stone, which does not revolve very rapidly, until the glass is sufficiently 'cut' (really rubbed away), when its position is altered, and the 'cutting' is continued on another part.

The source of lead-poisoning here is the large quantity of fine glass powder with which the wet hands are continually in contact, the glass containing lead. In connection with this, reference may be made to the occurrence of lead-poisoning among wood-polishers, due to the action of the 'sand' paper, really made with ground glass, already mentioned.

3. Type-founders and type-setters, with whom may be classed the setters of musical type. Type-metal is an alloy of lead, tin, and antimony.

Type-setters are exposed to absorption of lead from constantly handling this compound, and also from a common habit of holding type in the mouth while at work. Further, there is often a good deal of dust about in the type boxes and elsewhere derived from the type itself. Slight scratches on the hands favour the impregnation of the system with the metal so abundantly present.

4. The connection of weaving with lead-poisoning will appear very remote at first sight. But a knowledge of the construction of the Jacquard loom will show that with certain arrangements, which are common in some parts of the country, there is considerable risk. The long cords, known as 'harness cords,' in that form of the loom are kept taut by weights suspended at the end termed 'lingoes.' A small loom will have as many as 1,200 to 1,500 such lingoes and cords, a large one 5,000 to 6,000. The lingoes are rod-shaped weights about six to seven inches long when made of lead, and twelve to fourteen inches long when made of iron. About twenty of them make one pound in weight. As they hang from the harness cords they are almost all in contact, and in the process of weaving some of them are rising and falling almost continually. But there is also a good deal of oscillatory motion imparted to them through the shaking of the loom, especially in hand-looms. The waste caused by this friction and clashing is very considerable, and in four to five years, with hard work, a whole set of lingoes may be so worn away as to be too light for use. They are not rubbed away uniformly by attrition, but are worn in little notches, evidently due to striking against each other rather than to uniform friction. They will lose in this way some 30 to 40 per cent. in weight in four to five years. Taking the average weight of twenty lingoes to one pound, this would give 300 lbs. of lead to 6,000 lingoes, the loss of which, at 33 per cent., would give 100 lbs. of lead rubbed off in fine particles on an average during four to five years, or, say, over 20 lbs. per annum, and this from one loom only in a room. The amount of such dangerous material given off from some scores of looms in a weaving shed would therefore be a very serious matter, and cause grave danger of lead-poisoning to the workpeople.

It is not only unnecessary to use lead for lingoes, but it is much more expensive, and iron ones are also to be preferred, as they keep their shape and position better. The motion of the lingoes can also be considerably diminished by placing them all in a light framework. The use of leaden lingoes is happily going much out of use in some parts of the country, and iron ones are deservedly growing in favour.

In the manufacture of coloured wall-papers there are certain processes fraught with grave danger to the workmen from the nature of the materials employed, greatly increased by the mode of their employment in the production of certain effects.

Where a fine white ground is required, this is often produced by laying on white lead; minium is employed to produce red, and yellow is often produced by using other compounds of lead—viz. litharge, chromate, iodide, or the chloride which, combined with the oxide, is known as Cassel yellow.

The 'satining' of white paper consists in producing a fine lustrous coat, chiefly effected by friction of the coating of white lead. In this operation a great quantity of fine dust is produced, which is inhaled, swallowed, or becomes deposited on the skin. The danger of lead-poisoning is therefore very great.

'Velvet' paper, which has a dull rough surface, is produced by covering

the surface of the paper with an adhesive coating (starch, &c.), which is powdered with cloth, reduced to fine dust, and coloured with red lead, arsenical green, &c. It is easy to see what injurious effects may be produced during the production of this material.

Eulenberg mentions the polishing of garnets, as carried out in Hungary by means of revolving leaden discs, as resulting frequently in lead-poisoning.

Lead intoxication has also been traced to the use of leaden pipes, &c., in beer machines; to the use of syphons having leaden or badly-made white-metal fixtures, &c.

The extensive spread of lead-poisoning by means of drinking water affected by the leaden connecting pipes is familiar to all medical men.

Sanitary Precautions.—The mining operations are not, as a rule, calculated to induce any special danger of lead-poisoning, but there may be great harm done by allowing the water which is used in great quantities for washing the finer, broken ore, &c., to make its way into streams, ponds, &c.

During the smelting there is always more or less vaporised lead given off along with sulphur dioxide, &c., and with these vapours there is invariably present PbS, $PbSO_4$, $PbCO_3$, &c. Therefore, smelting always necessitates the employment of condensing chambers or other methods for preventing the escape of these vapours into the atmosphere, which can only occur with great detriment to neighbouring inhabitants and vegetation. In some lead works in this country, long flues, sometimes having accessory catch-chambers, &c., are constructed rising up the sides of hills, reaching to several miles in length, which act as condensers, and as much as five to six hundred tons of metal have been recovered by this simple means in a year at one manufactory. The collection and removal of this valuable harvest, won by very simple means for the owner, requires great precautions on the part of the workmen, and should above all things never be attempted until the whole of the parts are perfectly cooled. Besides lead, the flues may contain other products directly derived from the ore, or compounds produced during the smelting; e.g., arsenic, zinc, carbonate and sulphate of lead, thallium, tellurium, molybdate of lead, &c.

The condensation can be greatly facilitated, and danger avoided, by the assistance of water, which may be applied cold in the form of a rain or shower-bath, or as steam. By this means the fumes are thoroughly mixed with the watery vapour and the most satisfactory results are obtained.

In the manufacture of red lead there is a large amount of dust produced, of which only too palpable evidence can generally be obtained on entering the premises. The escape of dust or vapour from the furnaces should be most carefully avoided, as not only is there direct danger from the metallic dust, but it gradually becomes oxidised, and soluble salts are formed, with greatly increased danger to animal and vegetable life.

The grinding of the minium is also attended with danger, and should be carried out in a closed chamber, provided with well-fitting glass windows to allow of observation of the progress of the work. Subsequently the powdered minium has to be filled into boxes or barrels, an unavoidably dusty operation, during which the workmen should be protected by sponges or cotton-wool tied before the mouth and nose. The joints of the cases should be carefully closed by pasting with paper, &c.

The manufacture of white lead is much more dangerous when carried out by some processes than by others. The 'Dutch method,' already described, leads to the worst results—mainly from the destructive action of the acetate, which causes the skin to crack and leaves raw surfaces for the direct absorption of the poison. The wearing of gloves would afford protection in this process; and liberal inunction of the skin of the hands and face

is of great service. The conveyance of the salts, after collection from the surface of the lead spirals, should be effected with care, and if possible by the aid of shoots, well covered. But the grinding is the most dangerous part of the work. This should never be done, as is only too often allowed, with an ordinary hammer or pounder. The least dangerous method is pulverising by rollers, which can be so adapted as to discharge the broken-up material of any desired degree of fineness. The whole apparatus should be covered in completely, so as to prevent, as far as possible, the escape of the deadly dust; and an exhauster should be applied to supply fresh air, and draw off the dust into a special chamber, water bath, or other receptacle. For the great majority of purposes for which white lead is required, it would be quite as serviceable in the paste form, made up with oil, and prepared in this form it would be deprived of most of its dangers. In order to grind it up with oil, it is not necessary to dry the wet powder, as the water is forced thoroughly out of the powder. Thus several dangerous operations are completely avoided.

With regard to the personal hygiene of the workmen, there is a great deal to be effected by means which are simple and involve no hardships or difficulties whatever.

Above all, personal cleanliness is important, nay essential. If a workman who is all day in the midst of a very dangerous dust, which attaches itself to his hair, beard, skin, and clothes, enters his mouth and nose and ears, gets beneath his clothes and adheres to his skin, will not keep his body and clothes clean, then it is hopeless to try to afford him protection by any means to be devised. His hands and mouth are sure, after a few hours, to be fouled with lead dust; he should therefore rinse his mouth thoroughly from time to time, and wash his hands, and be most careful never to take any food, solid or liquid, until this has been done, and his teeth well brushed. The nails should be always kept cut short, as well as the hair and beard, as otherwise the poisonous dust will get deposited in them; the clothes should be made as tight-fitting at the neck and wrists as possible, and what is worn in the workshop should be left there, and another suit worn home. Warm baths should be provided for the workpeople in all such works, a thing which can be done at a very moderate cost, as if there is not actually hot water at hand, there is always steam, by which a bath of cold water can be quickly warmed. Every encouragement should be given to the workpeople to use these baths.

If circumstances prevent any of the men from leaving the works at meal times, it is essential that a room be provided for meals completely detached from the dust-producing works. Workmen who have already shown a predisposition to plumbism should not be allowed to continue the work; and all persons having an open cut or sore should be excluded until it is quite healed.

As already mentioned, there are stages of the work when some form of respirator is essential for the time, and fatty inunction is very useful to prevent the hands being cracked.

The constant use of acidulated drinks, e.g. lemonade made with sulphuric acid, or the administration of iodide of potassium for any length of time, is quite inadmissible. Small doses of sulphur, or of sulphide of sodium, are much less likely to undermine the health, and indeed can be continued for a long time without inconvenience, and even advantageously. They favour the formation of an insoluble sulphide of lead.

The drinking freely of milk, as is often recommended, can do no harm, if it be not done with the mouth still foul with lead dust; and if the milk be not kept stored in the workroom, where it may become a vehicle of poison to the drinker, if he escape other means of intoxication.

As a general measure of precaution it is highly desirable that the work-

men should be carefully examined by a medical man at short intervals, especial attention being shown to the 'gum-line,' the complexion, and the state of the nervous system.

No less cleanliness is to be constantly observed in the case of the workshops than in the person of the workman. They must be kept free from dust by constant sweeping of walls, floor, and ceiling, and washing when needful. The floors should be cemented, or well flagged, so that they can be thoroughly cleaned, and also kept moist, to allay dust; for which purpose a little chloride of calcium may with advantage be applied in solution to the floors.

Men inclined to excess in drinking are certainly more likely to be reckless and regardless of their own and others' welfare, hence they are a danger in lead works; whether they are actually more susceptible to the action of lead is not certain. Strict employers, careful of their men, may effect a great deal in encouraging them to attention to the rules of the shop, which should be printed in large form and hung up in every room. Such care generally bears good fruit in the health of the men, and the economical success of the works.

PHOSPHORUS

Phosphorus does not occur free in nature, but, owing to its great tendency to combine with oxygen, it is usually found united with that element and with metals. The glowing of phosphorus in the dark is due to slow oxidation. Phosphate of calcium is the most important of the natural phosphates. Dry bones contain some 88 per cent. of neutral phosphate of calcium. The fossilised excrement of extinct carnivora, under the name of coprolites, forms a large depôt of phosphate of calcium, of which guano also largely consists.

But for industrial purposes phosphorus is prepared from bone-ash, the best form of apparatus being that known as Flecks'. The bones are calcined to whiteness for some hours, then broken up or ground and treated with two-thirds of their weight of sulphuric acid and fifteen to twenty parts of water. The bone-ash is decomposed by the sulphuric acid, sulphate of calcium being formed. Most of the phosphorus is found in the liquid as superphosphate of calcium. The liquid is evaporated to the consistence of syrup, then mixed with one-fourth its weight of charcoal, and dried by heating in an iron vessel. The dried mass is heated to redness, and half the phosphorus distils over into the water, beneath the surface of which the neck of the retort opens, the other half remaining combined with calcium in the retort as pyrophosphate. The phosphorus thus obtained is impure, containing compounds of sulphur, silicon, carbon, also arsenic, charcoal, red amorphous phosphorus, &c. It is purified by pressing, when heated under hot water; or chemically by treatment with bichromate of potassium and sulphuric acid, or with nitric acid. It is usually sold in the form of sticks, the melted phosphorus being sucked into glass tubes by the use of india-rubber balls; or Seulert's apparatus is used—a tinned-copper vessel, from which the liquefied phosphorus flows through a horizontal tube with a tap, connected with which are suitable glass tubes into which the mass falls. When the tubes are filled the tap is closed and the phosphorus allowed to solidify.

During the burning of the bones most offensive vapours are given off, which also include offensive dangerous gases. The nuisance is perhaps more annoying, like many similar ones, to those living around the works than to those inside, but the danger is considerable to the workmen during various parts of the manufacture. Works for the production of phosphorus should not be allowed to be carried on in the immediate neighbourhood of towns.

Besides this ordinary yellowish phosphorus, there exist other forms due to molecular changes, without any recognisable change of chemical composition. A red or amorphous phosphorus is formed by heating phosphorus in a closed vessel. It consists of red scales, which do not become ignited on coming in contact with the air until it reaches a temperature above 260° C. (= 500° F.), when it becomes reconverted into the ordinary form. This red or amorphous phosphorus is prepared in a large way for the manufacture of 'safety' matches, as follows: Phosphorus is heated in a porcelain or enamelled iron digester, placed in a double bath, the one next the digester being filled with sand or paraffin, the outer one with an amalgam of tin and lead, melting at 250° C. (=482° F.). A tube, furnished with a stop-cock, leads from the digester, which is closed with a lid (which is again covered with a lid enclosing the bath), and dips into a vessel of stoneware or copper, made on the model of a Woulfe's bottle.

The vapours from the digester pass through this tube, and are condensed in this vessel. Any which are not condensed are carried off by a double-bent tube, and discharged under mercury in another receptacle, a layer of water being placed above the mercury.

Fumes resulting from the oxidation of the phosphorus, and of the arsenic and sulphur which exist as impurities in it, are given off during this process, including arseniuretted (AsH_3) and sulphuretted hydrogen (H_2S), phosphuretted hydrogen (PH_3), and phosphoric anhydride (P_2O_5). Hence great precautions have to be taken by the workmen to avoid the risks involved from inhaling these fumes.

Phosphorus is used on an enormous scale in manufacture, both as white phosphorus, and in its amorphous (red) form.

The manufacture of matches is so important as to deserve more than passing reference. In Sweden and Germany it is carried on on an enormous scale, and there are in Neustadt alone some seventy factories. So early as 1816, Derosne in Paris produced matches which were made with finely-divided white phosphorus and sulphur. Some twenty years later an improved method was introduced at a large manufactory established for the purpose at Frankfort-on-the-Main, by Trevany, Römer, and Böttger. Instead of chlorate of potassium, an expensive and explosive material, liable to cause injury to the user, and spoil the matches, they employed as the oxidiser peroxide of manganese, nitrate of potassium, litharge, brown lead (PbO_2, superoxide), nitrate of lead, &c., and other substances whose combustion is less violent than is the case of chlorate of potassium. Instead of gum arabic they employed glue to fix the mass to the wooden chips, a material which dries much quicker than gum. The wood is cut by machinery into thin plates, the thickness of a match, and these are subsequently cut into sticks of the required size. Round wooden matches are made by cylindrical knives, of which a number of the requisite bore are fixed in a frame. In smaller factories the machine labour is replaced by hand labour. The wooden stems are fixed in a frame, so that the ends shall all stand at one level, 3,000 to 6,000 in each, and dipped in the materials which make the 'head,' and fix it properly. As the phosphorus is so highly inflammable, it is necessary to interpose some slower medium between it and the wood, otherwise the phosphorus would be burned out without the wood ever becoming ignited. Sulphur is very commonly used for this purpose, when resinous wood is employed; in the case of non-resinous woods, such as elm, birch, poplar, aspen, &c., wax, paraffin, &c., are used instead of sulphur. The sulphur is melted in a shallow iron pan, at as low a temperature as possible, to avoid ignition, or the passage of the sulphur into a thick unworkable condition. The most suitable temperature is about

235° F. In some works double-walled receptacles are used, with steam at this temperature circulating between. The wooden stems, fixed in their frame, having been warmed on a sort of hot-hearth close at hand, to ensure more even distribution of the molten sulphur, are dipped into it to the required depth and raised, superfluous sulphur being removed by giving the frame a shake. In smaller factories considerable danger arises from all the operations being carried on in the same place, and the same fire often being employed for the sulphuring and the subsequent application of the igniting material. Owing to this the workmen are exposed to the vapours of phosphorus, as well as to others arising during the sulphuring, which is often carried on at such a temperature as to cause danger not only of its ignition but also the development of sulphur vapour to a most distressing degree.

The igniting mass is formed of white phosphorus, which should not amount to more than 6 to 8 per cent. of the mass [1] melted under hot water, and mixed with some of the oxidising materials already mentioned, and some kind of material to fix it on the match (usually glue, dextrin, gum, &c.), and some colouring material (such as umber, ultramarine, lampblack, and various aniline colours, &c.); this is used either hot or cold. The fixing medium is first dissolved in water, then heated in an enamelled iron pot, with a very exactly fitting lid; the phosphorus is then added, and the lid, to which a stirring apparatus is fixed, carefully closed. When the phosphorus is thoroughly distributed, the colouring matter and oxidiser are added, and after careful stirring the operation is complete.

The likelihood of phosphorus fumes escaping during these processes, to the detriment of the workmen, is very great, and to obviate the risks it requires careful management and good appliances. Subsequently the matches are left in the frames in warm air (not much above 85° F.), until they are quite dried, when they are taken out of the frames, and made up in bundles, or put direct into boxes. The drying should never be done by the direct heat of a fire, but should always be effected by a current of warm air. In some works—and it is most desirable that the method should be universally adopted—a good deal of this work is done by machinery. The workmen are exposed to great risk here from vapour arising from the matches, from fire, and from the action of the match heads on the skin, especially if it should be raw or sore.

'Safety' matches are made with red or amorphous phosphorus, which, as stated, does not take fire in the air until heated above 260° C. (= 500° F.), when it is converted into the ordinary form of phosphorus, and burns with formation of phosphoric anhydride. The phosphorus is contained in the rough rubbing surface on the box, and not in the match-heads. This igniting material is fixed by glue, or other suitable medium, to the surface, and is composed of chlorate of potash, from 10 to 40 per cent. iron pyrites, peroxide of manganese, powdered glass, sulphide of antimony, and a suitable adhesive—e.g. of glue.

These materials are ground and mixed to a fine paste. Great care is requisite to prevent the chlorate of potash exploding, and with this object it is ground in a wooden vessel, provided with a special cover for allowing immediate escape to the gases should an explosion occur. The adhesive is first dissolved in boiling water, next the lead compounds are added, and the other constituents afterwards; the chlorate of potash being added last. The rubbing surface is prepared in a similar way, the amorphous phosphorus being added last.

[1] In England the proportion is commonly much larger, but this only renders the match more dangerous as an explosive, and as affecting the health of the maker; a smaller proportion is quite as efficient for ignition.

The match-sticks are dipped in a mixture consisting of chlorate of potash, peroxide of manganese, bichromate of potash, red lead, subsulphide of lead, and sometimes picric acid, with a suitable adhesive, such as starch, glue, &c. As in the case of ordinary matches, some material is added to diminish the violence of the ignition, such as sulphur, oxide of iron, umber, powdered glass, &c.[1]

The people engaged in the manufacture of phosphorus and its compounds, and in their utilisation for commercial purposes, are exposed to grave danger at various stages of the work, and at certain stages great nuisance is caused to those living around the works. Those engaged in the earlier stages of bone-burning, and such preparations, may live fairly healthy lives, if even moderate care be taken, but the manufacture of matches is often carried on so as to imperil the health and lives of the workpeople grievously. There is one disease, unfortunately too well known, which is specific to those engaged in this trade, that is, the disease of the bones (phosphorus-necrosis), which is mostly limited to the jaws, and more particularly to the lower jaw.

There is no reason why the bone-burning should not be carried on subject to the action of a fan which would conduct the offensive fumes either directly into a furnace, where the offensive odour would be destroyed, or still better, into a reservoir containing water, where they would be condensed, and the accompanying fumes would either be absorbed or conducted further, after passing through the bath, into a high chimney. Dust from the burned bones is very liable to cause irritation of the eyes and mucous membranes, which is often very troublesome.

During the subsequent distillation of the bones, very offensive vapours are produced, which can be best treated as suggested above. When the bones are treated with sulphuric acid, sulphuretted hydrogen and carbon dioxide are freely developed, as well as smaller quantities of compounds of hydrogen with chlorine, fluorine, and arsenic, also hydrocyanic acid. Subsequently, when the mass becomes heated, sulphuric and sulphurous acids are evolved in large quantities, and, as the sulphuric acid is impure, arsenic and arsenious acid are always present. Active ventilation is absolutely essential to prevent danger from these gases. It has been suggested to conduct them into a receptacle filled with burned bones—which would facilitate their disintegration.

During the distillation of the impure phosphorus, dangerous gases of a similar character are evolved, and the fire must be gradually lowered to avoid ignition of the phosphorus which has condensed on the sides of the receptacles. The workmen who fill and empty the retorts should always be carefully dressed, so as to protect as much of the surface of the body as possible, and wear masks provided with glass protectors for the eyes, while the respiratory organs should be protected by cotton-wool or cloths. In this stage of the work, free ventilation to dilute and expel the gases is essential. When the retorts have been heated, they must never be opened more than is absolutely necessary, and they must be slowly cooled to prevent the risk of fracture, and the escape of phosphoric vapours in great quantities. In the rectification of phosphorus with nitric acid, extreme care must be taken to make all parts of the apparatus which conducts away the nitrous fumes (vapour of

[1] Efforts, which it is to be hoped may be crowned with success, are continually being made to produce a match without the use of phosphorus. As oxidisers the following have been tried: nitrate of lead, picrate, chlorate, bichromate and permanganate of potash, &c.; as the igniting substance, iron pyrites, sulphur, carbon, &c.,; and as substances to diminish the force of explosion, sand, powdered glass, umber, with the same adhesives as are used in the case of other matches.

phosphorus, &c.), air tight. The admixture of a stream of CO_2 would be advantageous as diminishing the risk of explosion.

As the vapour of phosphorus, owing to its weight, sinks to the ground, it is of the greatest importance to employ aspirators to enforce an upward current of air in the workshops.

The storing of phosphorus is a matter which should be done with the greatest foresight and care. It should always be kept in glass or earthenware vessels in water, and still better in such vessels which are placed inside another of the same kind for greater safety. These should be kept in a cool place away from all risk of breakage.

During carriage, these should be enclosed in metallic (tin) vessels filled with water, and made to hold only a certain maximum quantity, and not to exceed a certain maximum weight. They should be provided with proper means for being lifted, to avoid danger, and invariably be labelled to show which is the upper side.

The manufacture of red or amorphous phosphorus may lead to the development of similar gases to those evolved in the distillation of white phosphorus, owing to the impurities in the phosphorus which is used for conversion into the red form; but though cases of intoxication do occur from this substance, they are rare as compared with those caused by white phosphorus. The operations can, however, be conducted in a less dangerous manner, but if care be not taken, in the closing of the digester, to make it air tight, and in the opening of it to avoid the escape of the noxious fumes, the workmen will unavoidably be exposed to most offensive and dangerous fumes.

That water which has been used during the process of manufacture, and contains any phosphorus or other dangerous ingredient, should not be allowed to leave the works untreated, and more particularly to enter any well or stream, is a matter of primary importance. It has been found profitable and otherwise advantageous to evaporate such water in shallow pans placed inside the machinery. A considerable quantity of phosphorus may be recovered in this way.

The greatest of all the industries in which phosphorus is engaged is match-making. From the description given of the process, the nature of the dangers incurred will already be understood.

As might be expected, all the evils connected with the trade are found in their worst form in small factories, and where the work is carried on in the workmen's houses. Here it is impossible to provide the large airy rooms, the artificial ventilation, the air-tight receptacles, and other things which are essential to the carrying on the work without serious danger to the workpeople.

At the very commencement of the operation of match-making, the workpeople are exposed to great, and even serious inconvenience from a cause which is quite preventable. When the cut chips are brought for dipping, the bundles contain a great quantity of the finest wood dust, which is liable to cause irritation of the respiratory passages. This could be easily prevented by exposing the chips to the action of a fan for a short time.

The more serious affections, however, from which the match-makers suffer are those arising from the presence of phosphorus in the match-heads, and from the sulphur employed in the manner described. If the sulphur be heated too much there is danger of ignition, and of the development of large quantities of noxious fumes. At the best it requires more attention than is usually devoted to the matter to prevent the temperature of the sulphur being unnecessarily raised, and the consequent production of SO_2 in considerable quantities; there is always some given off during this process.

The pans in which this sulphuring is done should be covered with a proper lid, provided with a pipe to conduct away the fumes into a tall chimney, if they cannot be utilised, as such things usually can be. In small factories the sulphuring and the dipping in the explosive, which contains the phosphorus, are often done at the same fire, and with no arrangements for protecting the workmen from the combined action of sulphur and phosphorus fumes.

The preparation of the explosive material is the most dangerous part of the whole manufacture.

This should be absolutely prohibited in cases where it can only be done in open vessels; and the provision of proper vessels heated by steam or water, with air-tight covers, means of carrying off offensive vapours, and safety-valves to prevent danger from explosion (by permitting the ready escape of gases suddenly evolved) should be made a *sine quâ non.*

The employment of a warm adhesive (glue, &c.) has such disadvantages that the use of cold starch and dextrin has been suggested as an advantageous substitute. But this does not quite meet the difficulties, as it is necessary to dry the cold adhesive at an increased temperature, which in turn leads to the evolution of phosphorus vapours. When gum has been used as a fixer, the 'head' is very liable to soften, come off, and adhere to the hands if they are at all moist from sweat, &c., and it is on the whole better to use glue as a fixer, as it dries so much quicker (30 to 40 minutes), and its disadvantages are so much more quickly got over.

The removal of the finished matches from the frames, and the putting them up in bundles for boxing, or in larger packets, involves considerable danger of ignition; and some part of the 'heads' is liable to get rubbed off in the form of dust, and to adhere to the skin and cause absorption or irritation of any existing raw places. Great caution is required in the operation, and vessels of water should always be close at hand.

The importance of large roomy workshops with good ventilation, assisted by fans or flues set in action by heat (connection with the chimney, &c.), cannot be over-rated, the ventilation being directed *upwards*, to counteract the tendency of the heavy vapour to sink; extreme personal cleanliness, maintained by frequent baths and washing of the mouth and hands, especially before partaking of food, should also be constantly observed.

No food or drink should be taken in the workshop, and the working clothes should not be worn at home.

A very important condition of preservation of the health of these workers is the diminution of the work to the shortest possible time, and, where it is possible, to allow those engaged in the more dangerous part of the work (e.g. the preparation of the material for ignition) to take on at intervals some other work for a time. The benefits to be derived from the presence of the vapour of turpentine, as described first by Letheby, have been generally recognised, and in many works little vessels of tin containing turpentine are placed in the workshops, and the workpeople carry flasks or sponges attached by a string at their chests, so that they may have the advantage of breathing air impregnated with the vapour. Its administration internally in case of phosphorus intoxication is recommended. Advantage is also to be derived from washing the mouth with a weak alkaline solution—e.g. carbonate of sodium. Washing the teeth with this, or with lime-water and charcoal, is also to be recommended. The use of masks filled with charcoal has also been recommended.

Where the benefits of the oxidation derived from turpentine vapours cannot be utilised, owing to individual inability to endure the turpentine

fumes, it has been recommended to use watery solution of sulphate of copper, as it leads to precipitation of phosphorus as phosphate, along with metallic copper. The addition of charcoal, a powerful absorbent of phosphorus, to the solution would also be beneficial.

The effects of poisoning with phosphorus may be either acute or chronic. The symptoms appear much more rapidly after swallowing phosphorus when finely divided than when in a solid piece.

Chronic intoxication is generally slow and insidious, and seldom shows itself for three to four years after the commencement of work in a factory. It is much more common in match-factories than in any other works connected with the use of phosphorus. Before any very marked symptoms are noted, there are observable loss of flesh and a gradual change of colour to a yellowish tinge. The appetite fails, and gastric and intestinal disorders are common; indeed, gastric catarrh might be commonly supposed to be the chief ailment. Headache and dulness of the mental faculties become marked, and dyspnœa and bronchitis are common. Toothache and pains in the jaws become almost constant; later on the gums swell, become tender, and ulcers form, discharging large quantities of stinking matter, and the ulceration tends to extend and become very destructive. At the same time the breath becomes very offensive.

Then the bone can generally be found to be diseased by the use of the sound. In a more advanced stage the gums as well as the periosteum become quite detached from the bone, and the alveolar processes are exposed to view. The course of events is usually more rapid and serious when the lower jaw is attacked than when the upper one is, disease of the latter being much the less frequent, in the proportion of about three to five, possibly because the lower jaw is more in contact with the saliva, which always contains phosphorus—the cause of all the evil. Sometimes the necrotic action proceeds stealthily, and not in the somewhat stormy manner which is usual, and the patient will lose many teeth before any other serious symptoms appear; or a long sequestrum may be discharged before he has realised the true state of affairs. The existence of carious teeth is commonly assumed to be the chief agency in the commencement of the disease, by giving an entry to the phosphorus into the interior. General breakdown of the health is a natural result of such a condition, the intoxication, pain, and malnutrition combining to reduce the patient to the most miserable state. The frequency of this frightful disease, according to Hirt, was formerly not less than 11 to 12 patients yearly to every 100 matchmakers, without regard to age or sex; its gravity may be judged from the statement that one in two attacked are said to die, the condition of many who recover from a severe attack being most wretched. It is now not common in this country.

The complete suppression of the use of white phosphorus is the great preventive. Failing that, suitable large rooms; good ventilation artificially conducted upwards; suitable apparatus to carry off vapours and dust; and personal care on the part of the workpeople—are what must be relied on to avert or minimise the evils.

ZINC

Zinc is never found native, but its ores occur in abundance. The chief are calamine, or carbonate of zinc, blende, or sulphide of zinc, and a red oxide, the colour of which is due to the presence of the oxides of iron and manganese.

The extraction of zinc from its ores commences with the crushing of the ore, which is subsequently roasted, during which process, when blende is used, the sulphur passes into sulphur dioxide, the zinc becomin oxidised. The

roasted ore is mixed with half its weight of powdered coke or anthracite and subsequently reduced (deoxidised) by one of two processes, known as the English and the Belgian. The English method is one of distillation downwards (*per descensum*). The above mixture is put into crucibles having an opening in the bottom with a short iron pipe, and a lid which is carefully luted over. A number of these crucibles are placed on the fire-bars within a circular furnace. After a time carbonic oxide escapes through the pipe in the bottom, and burns with a blue flame, which becomes white and deposits white fumes of oxide of zinc. This flame is then extinguished, and a longer tube attached, through which the metal falls into vessels provided to receive it below. As the zinc is volatile at high temperatures, and boils at a bright red-heat, it distils downwards in this way. The metal thus obtained is impure and contains a good deal of oxide and requires remelting and skimming, after which it is cast into ingots; but the commercial zinc usually contains some lead and iron as impurities.

Zinc is very little acted on by the atmosphere. It loses its brilliancy when exposed to moist air, owing to the formation of a thin pellicle of oxide, which protects it from further change. This property and the facility with which it can be rolled into sheets when hot make it available for many uses. It is largely used in the form of 'galvanised' iron-sheets for roofing, &c. The sheets of iron are covered with a coating of zinc either by being dipped in molten zinc, covered with a layer of sal-ammoniac, which dissolves the oxide which forms on the zinc; or by first coating the zinc with tin, by galvanic action, and then dipping in the molten zinc.

Galvanised iron wire is also very largely in use for various purposes, of which the most important are for telegraph wires and for wiring down champagne, mineral waters, and other effervescing drinks. Brass and copper are also sometimes zinced. Galvanic zincing is done by placing the metal to be galvanised in a zinc bath filled with a saturated solution of sulphate of zinc.

Zinc is also used to form important alloys; brass consists of one part of zinc and one of copper, and german silver is brass to which some nickel has been added. Zinc plates are extensively used as the oxidisable plate in a great many forms of galvanic batteries, owing to its solubility in dilute acids, with evolution of hydrogen.

Zinc is not absorbed by the skin, and its effects on the organism are limited to absorption of its vapour, through inhalation, or inhalation of the dust. Dust is created in large quantities in the grinding of the oxide, and precaution should be taken to have this done in suitable closed chambers and to protect the workmen by respirators when they are obliged to enter the grinding chamber.

Exposure to the action of the vapour of zinc for some time may produce serious symptoms of intoxication: cough and difficulty of breathing, headache, giddiness, stiffness in the limbs, sickness, and vomiting. Copious sweating sometimes occurs.

The severe colic and irritation of the skin which is sometimes observed in persons exposed to the action of zinc dust, &c., is most likely due to the action of impurities, e.g. lead or arsenic, and not to zinc. But the powder, acting merely as a mechanical irritant, may cause considerable cutaneous irritation.

Some writers consider that the nervous system is injuriously affected by exposure to the action of zinc, but only after many years, the reflex and motor systems being chiefly affected. It has undoubtedly been noticed that farmyard poultry (especially ducks) have been affected with spasms of the legs and even paralysis when ashes from a zinc furnace had been left in their feeding ground.

The proper condensation of the vapour is the great desideratum, and vigorous ventilation to free the workrooms from it.

Those engaged in the wiring of champagne bottles with 'galvanised' wire have been observed to suffer from stomatitis, inflammation of the gums, salivation, fœtid breath, ulcers of the gums and tonsils, and similar symptoms have been noticed among coopers using zinced iron hoops. It appears not improbable that these dangerous symptoms were due to arsenic, so commonly present in commercial zinc.

It is important that the vapour and dust be not allowed to escape from the works so as to injure the vegetation or water-courses in the neighbourhood, and wash-water, &c., from the works should not be admitted into streams, wells, &c.

SLAUGHTER-HOUSES

AND

THEIR ADMINISTRATION

BY

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SLAUGHTER-HOUSES AND THEIR ADMINISTRATION

Among the many industries which exercise a direct or indirect effect upon the public health, there are probably none of greater importance than those which centre in the meat supply. Little need be said in support of the need for measures to ensure that meat intended for consumption as food shall be good and wholesome in quality. Apart, however, from the actual quality of the meat, and the processes by which it is prepared for sale and consumption, we have also to deal (*a*) with the transport and storage of live-stock, as also with the preservation of imported carcases, (*b*) with the keeping of animals, (*c*) with the slaughtering of animals, and (*d*) to a certain extent with several important branches of industry in which animal matters or substances of animal origin are dealt with. The manner in which this variety of associated businesses is conducted in different towns and districts is very diverse: the general principles may be the same, but local custom, expediency, profit, or convenience, or extent of supervision lead to variations in detail which exercise a great influence upon the general aspect of the business and its effects upon health.

It is well known that among the commonest causes of 'nuisances, or conditions prejudicial to health,' is pollution of the atmosphere, which not only produces bodily discomfort, but tends by continuance to induce an appreciable impairment of health and strength. A large abattoir, or even a small slaughter-house, may be an important element of atmospheric impurity, and the more dense the population in its vicinity, the more necessary it becomes to mitigate its evils by careful management; for under appropriate conditions of site, structure, and management the business may be so carried on as to cause neither offence nor injury of any kind. There is no difficulty whatever in laying down the general principles upon which appropriate means of preventing or minimising nuisances must be based, but in dealing with any particular establishment it is often a matter of difficulty to apply these principles to the best advantage, since their application depends upon a variety of considerations, an important one frequently being original defects of site and structure, arising from attempts to adapt old buildings, not originally intended for the purpose, to the requirements of slaughter-house, lairage, or other offices; this often implies an absence of conveniences which are necessary not only to facilitate cleansing but to prevent defilement. Or the nuisance may be dependent upon (1) accumulation of filth on or about the premises, or on its removal from the premises in an offensive condition; (2) on a generally filthy condition of the interior of the buildings and the premises and utensils generally; (3) on an improper mode of disposing of offensive refuse, liquid or otherwise, and carelessness in the reception of offensive materials. For these the obvious remedy is a supervision that will ensure cleanliness in the broadest sense of the term, and a close observance of carefully drawn bye-laws which bear upon the subject.

The importation and transport of cattle are regulated by orders of the Privy Council under the Contagious Diseases (Animals) Acts. An order under this

Act provides for landing-places for such foreign animals as are subject to slaughter ; it also defines quarantine stations for animals not subject to immediate slaughter, and also specifies landing-places for foreign animals which are permitted to travel, being subject neither to quarantine nor slaughter. Most of the livestock imported from or through the United States is landed at Liverpool (Woodside), and as these cattle are not permitted to travel, they are slaughtered on landing, the carcases being forwarded to their destination. Canadian cattle are subject to a short detention or 'quarantine,' and to an examination by an inspector appointed by the Privy Council, upon whose responsibility they are passed on. No restrictions of these kinds are placed upon the moving of animals within the United Kingdom, but the Contagious Diseases (Animals) Acts contain provisions restricting the movement of cattle within infected areas and under certain conditions, and these Acts require all railway trucks, lairages, pens, &c., used in the transport or temporary accommodation of cattle to be lime-washed and purified, before twelve o'clock on the day following their use, or before they are again used for any purpose.

As evidence of the large import trade it may be mentioned that close on 400,000 cattle, 383,000 sheep, and 156,000 swine are landed annually at the port of Liverpool alone, besides 163,000 tons of fresh and preserved meat.

The following extracts from the Animals Order regulating disinfection of vessels and transit by water are important :—

Vessels

100.—(1) A vessel used for carrying animals by sea, or on a canal, river, or inland navigation, shall, *after the landing* of animals therefrom, and *before the taking* on board of any other animal or other cargo, be cleansed and disinfected as follows :

(i) All parts of the vessel with which animals or their droppings have come in contact shall be scraped and swept : then

(ii) The same parts of the vessel shall be thoroughly washed or scrubbed or scoured with water : then

(iii) The same parts of the vessel shall have applied to them a coating of lime-wash : except that

(iv) The application of lime-wash shall not be compulsory as regards such parts of the vessel as are used for passengers or crew.

(2) The scrapings and sweepings of the vessel shall not be landed unless and until they have been well mixed with quicklime.

(3) Except that in the case of a ferry-boat or other vessel which makes short and frequent passages across a river or an arm of the sea or other water, it shall be sufficient if the ferry-boat or vessel be cleansed and disinfected once in every period of twelve hours within which it is so used.

Fodder and Litter

101.—(1) All partly consumed or broken fodder that has been supplied to, and all litter that has been used for or about, animals carried by sea, or on a canal, river, or inland navigation, shall, when landed from the vessel, be forthwith well mixed with quicklime and be effectually removed from contact with animals.

(2) Nothing in this Article shall apply to fodder or litter supplied to or used for or about foreign animals.

Movable Gangways and other Apparatus

102.—(1) A movable gangway or passage-way, cage, or other apparatus, used or intended for the loading or unloading of animals on or from a vessel, or otherwise used in connection with the transit of animals by sea, or on a canal, river, or inland navigation, shall, as soon as practicable after being so used, be cleansed as follows :

(i) The gangway or apparatus shall be scraped and swept, and all dung, litter, and other matter shall be effectually removed therefrom : then

(ii) The gangway or apparatus shall be thoroughly washed or scrubbed or scoured with water.

(2) The scrapings and sweepings of the gangway or apparatus, and all dung, litter, and

other matter removed therefrom shall forthwith be well mixed with quicklime, and be effectually removed from contact with animals.

Landing Places

110.—(1) Where an animal at a place of landing or place adjacent thereto is affected with disease, that place and every other place where the animal is or since landing has been shall not be used for any animals other than animals brought thereto with that animal (in the same vessel or otherwise) unless and until the place has been, as far as practicable, cleansed and disinfected.

(2) Nothing in this chapter shall apply to a Foreign Animals Wharf, nor to a Foreign Animals Quarantine Station, nor to a landing-place for foreign animals.

Offences

172.—(1) If the slaughter of animals is not commenced at the time directed by the Privy Council under this part, or completed in accordance with the provisions of this part, the person failing to cause such slaughter to be so commenced or completed shall be deemed guilty of an offence against the Act of 1878.

(2) If any dung of animals, or any fodder, litter, utensils, pens, hurdles, fittings, or other thing is landed or removed in contravention of this part, the owner thereof, and the owner and the lessee and the occupier of the place of landing or other place where or from which such dung or other thing is landed or removed, and also in the case of the landing thereof, the owner and the character and the master of the vessel from which the same is landed, shall, each according to and in respect of his own acts or defaults, be deemed guilty of an offence against the Act of 1878.

Fittings of Vessels

116.—(1) Every place used for animals on board a vessel shall be divided into pens by substantial divisions.

(2) Each pen shall not exceed nine feet in breadth or fifteen feet in length.

(3) The floor of each pen shall, in order to prevent slipping, be strewn with a proper quantity of litter or sand or other proper substance, or be fitted with battens or other proper footholds.

(4) Every such place, if enclosed, shall be ventilated by means of separate inlet and outlet openings, of such size and position as will secure a proper supply of air to the place in all states of weather.

Overcrowding

117.—A vessel bringing animals to any port or place in England or Wales or Scotland from any port or place in the United Kingdom shall not be overcrowded so as to cause unnecessary suffering to the animals on board.

Shorn Sheep

118.—Between each 1st day of November and the next following 30th day of April (both days inclusive) shorn sheep shall not be carried on the deck of a vessel, except where they were last shorn more than sixty days before being so carried.

Gangways for Sheep-Pens

119.—Where sheep are carried on the deck of a vessel, proper gangways shall be provided either between or above the pens in which they are carried.

Detention

120.—Animals landed from a vessel shall, on a certificate of an Inspector of the Privy Council, certifying to the effect that the provisions of this chapter, or some or one of them, have not or has not been observed in the vessel, be detained, at the place of landing, or in lairs adjacent thereto, until the Privy Council otherwise direct.

Shipping and Unshipping Places

Water

121.—At every place where animals are put on board of or landed from vessels, provision shall be made, to the satisfaction of the Privy Council, for a supply of water for animals; and water shall be supplied there, gratuitously, on request of any person having charge of any animal.

Food

122.—At every place where animals are landed from vessels, provision shall be made, to the satisfaction of the Privy Council, for the speedy and convenient unshipment of

animals and for a supply of food for them; and food shall be supplied there, on request of any person having charge of any animal, at such price as the Privy Council from time to time approve.

Landing and Treatment of Dung, Fodder, &c., of Animals which are intended to be landed at a Foreign Animals Wharf

164.—(1) No dung of foreign animals that have been or are intended to be landed at a Foreign Animals Wharf, and no partly consumed or broken fodder that has been supplied to such animals, and no litter that has been used for or about such animals, shall be landed without the previous consent in writing of the Local Authority of the place where it is intended to land such dung or other thing.

(2) All such dung and all such partly consumed or broken fodder and all such litter shall, when so landed, be forthwith well mixed with quicklime and be effectually removed from contact with animals.

OFFENCES

126.—If anything is done or omitted to be done in contravention of any of the foregoing provisions of this part, the owner and the charterer and the master of the vessel in which—and the owner and the lessee and the occupier of the place where animals are put on board of or landed from vessels at which—and the railway company carrying animals on or owning or working the railway on which—and also, in case of the overcrowding of a vessel, or of a railway truck, horse-box, or other vehicle on a railway, or of the carrying on a railway of sheep shorn and unclothed, the consignor of the animals in respect of which (as the case may be)—the same is done or omitted, shall each, according to and in respect of his or their own acts or omissions, be deemed guilty of an offence against the Act of 1878.

In regard to the storage of livestock, it is evident that animals sent to a slaughter-house are not, under ordinary circumstances, detained there for any lengthened period; nevertheless, as soon as one batch is slaughtered another set replaces the first, and the result, so far as the keeping of animals is concerned, is precisely the same as would be the case were a number kept permanently upon the premises. The Public Health Act, the Nuisances Removal Act, and local Acts generally recognise the fact that animals may be so kept as to be a nuisance injurious to health, and the necessity for the regulation and control of the keeping of livestock—more especially where human population is aggregated—is sufficiently obvious.

The nuisances arise from defects in structure of the lairages, from insufficient space, from defective drainage and water supply, and accumulations of filth and the like. Soakage of putrefying animal matters through badly paved floors is one of the means of pollution of soil and contamination of wells, streams, &c. Defective ventilation is perhaps the evil most commonly met with in places where animals—more especially dairy cows—are kept in towns, and the results are very serious. Stall-fed dairy cows are exceedingly prone to tubercle, and it is not improbable that 30 or 40 per cent. of all dairy cows kept in towns are affected by it. Confinement, bad air, and the drain of constant milking are doubtless the predisposing causes.

The remedies for the harmful conditions arising from the keeping of animals are to be sought in the proper construction of the sheds, cleanly management, and proper storage of food, &c. These points will be referred to in connection with the lairages of public abattoirs. We turn meantime to the slaughtering of animals.

Slaughter-houses, be they public or private, large or small, require to be specially constructed to meet the necessities of the trade carried on within them. Of equal importance is it that their site in regard to inhabited dwellings should be carefully chosen. It is instructive to read the accounts of medical officers of health, both metropolitan and provincial, of conditions which existed some few years back in some of the slaughter-houses of their

respective districts. It appears that in one important and populous metropolitan locality there were twenty-four slaughter-houses, which, with one or two exceptions, were situated side by side. 'All of them,' we read, 'have a direct communication with a shop facing the street, and six of them have no other means for the entrance of cattle than by their passing across the public footways and through the shops, which are low and narrow.' They appear to have been separated from one another mostly by dwarf partitions; and from the lairs, which are often employed as hanging sheds for the meat, by like partitions of wood. When reported on they were described as being 'in a state of general disrepair; the roofs dilapidated, the flooring uneven and broken, the side walls filthy and blood-stained, the drainage defective and sluggish, the water supply inadequate and badly placed. Accumulations of dung, offal, and blood were general, and liquid manure was allowed to run freely into the sewers.' Clearly such premises as these cannot be other than prejudicial to health, and the question is whether entire reconstruction or removal altogether from the district would be the more efficient remedy. Again, we learn from a report upon another urban district that slaughtering is (or was) 'carried on in shops, lairs, stables, cellars, inhabited dwelling rooms and passages, as well as in open yards and on door steps; the slaughtering places, moreover, being in a majority of instances closely contiguous to the residence of the butchers, and generally approached through the shop. Most of the slaughter-houses are not open to the roof, living or bed rooms being situated over them, there being, moreover, in a large proportion of them, direct communication with the inhabited portions of the premises. Many of the slaughter-houses are absurdly small; the ventilation is generally described as deficient, bad, very bad, or "none," while in a considerable number there is no water supply within the slaughter-house.' It need hardly be added to complete this astonishing picture that lairage is, as a rule, conspicuous by its absence, and that, where provided, it is of the most inadequate description, whether regard be had to the dimensions or position, or to the relations of the lairs to other parts of the premises. Another account is given, 'where sheep and oxen are slaughtered in the shop forming part of the dwelling-house, it is customary to see a blood-hole, about two feet square and eighteen to twenty-four inches deep, in the middle of the shop floor. In this at the time of slaughtering the blood is collected, and the practice is to throw in sawdust, with the object of sopping up the blood, so as to permit of the blood being readily removed the following morning by the public scavenger. Most of the blood-holes, however, when inspected, had not been thoroughly emptied and cleansed, enough blood having been left at the bottom and corners to give rise to putrid emanations, whilst the effluvia from animals pounded within the house diffused themselves throughout it.' These of course are accounts of conditions existing in slaughter-houses a few years back, and it may be said that they do not apply exactly to existing conditions; however, an approximation to the state of affairs described is by no means a rarity, while there can be no question that plenty of examples of slaughter-houses, private, semi-private, or even public, are to be met with, which in site, structure, and in every particular, are unsuited to their purpose, and in no respect are conducted as they should be. Furthermore, it is important to note that it has been due to pressure from without that these revolting details have been modified, rather than to any effort on the part of those engaged in the trade to improve its conduct, accommodation of the most meagre description with a minimum of attention satisfying the very modest requirements of many butchers. We learn an important lesson here.

It will be observed that the least satisfactory conditions have been, and still are, associated with *private* slaughter-houses, for such an aggregation as has been previously described is not to be regarded as a public abattoir. We shall presently refer to public abattoirs and to the advantages which they present, and in the meantime deal with private slaughter-houses.

In most towns the proprietors of small slaughter-houses are licensed for a retail business only; i.e. the licensee is permitted to slaughter only those animals of which he disposes in the course of his ordinary business. A wholesale licence enables him to slaughter for other butchers, and to permit other butchers to slaughter on his premises. In both of these instances the places of business are private. At the present time almost every sanitary authority has adopted bye-laws for the control and management of these places. The bye-laws of various districts have a more or less close resemblance to one another, particulars and details being modified by local customs. Among the oldest and best are those of Liverpool, made in 1849, and acted upon since that time. They are almost identical with the Model Bye-laws of the Local Government Board, and may be taken as the type in common use. They embrace regulations for registering and inspection of slaughter-houses, and for keeping the same in a cleanly and proper state, and for removing filth therefrom at least once in every twenty-four hours, and for requiring that they should be provided by the occupier with a sufficient supply of water.

FIRST

The Occupier of any Slaughter-house, who shall at any time after the date of the certificate at the foot of his licence, and without the assent in writing of the Borough Engineer, Medical Officer of Health, or Building Surveyor for the time being, make any change or alteration whatsoever, or permit or suffer any change or alteration whatsoever to be made in the Slaughter-house or Building to which such licence applies in respect of the drainage of the same;

Or

In respect of the flagging or paving of the same;

Or

In respect of the ventilation of the same;

Or

In respect of the supply of water to the same;

Shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such change or alteration shall be continued and unremedied.

SECOND

The Occupier of any Slaughter-house who shall neglect or omit to cause the same to be thoroughly whitewashed with quicklime to the satisfaction of the Medical Officer of Health for the time being, at least once during the first ten days of each and every month, shall, for such neglect or omission, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such neglect and omission shall continue.

THIRD

The Occupier of any Slaughter-house who shall erect, build, or construct, or who shall permit or suffer to be erected, built, or constructed, or who shall permit or suffer to be, remain, or continue, within any Slaughter-house, any privy, middenstead, or cesspool, or any opening, access, or communication from such Slaughter-house to any such privy, middenstead, or cesspool, shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such privy, middenstead, or cesspool shall be, remain, or continue, within such Slaughter-house, or during which any such opening, access, or communication shall be, remain, or continue, from such Slaughter-house to such privy, middenstead, or cesspool.

FOURTH

The Occupier of any Slaughter-house who shall keep, or feed, or permit or suffer to be kept or fed, within such Slaughter-house, any swine, fowls, or other animals whatsoever,

used for human food, save and except such cattle as shall from time to time be brought to such Slaughter-house for the purpose of being there slaughtered, shall, for every such offence, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such swine, fowl, or other animal shall remain and continue in such Slaughter-house.

FIFTH

The Occupier of any Slaughter-house who shall keep or retain, or permit or suffer to be kept or retained therein, any cattle for a longer period of time than seventy-two hours previous to the slaughtering of the same, shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*.

SIXTH

The Occupier of any Slaughter-house who shall neglect or omit to cause the same to be thoroughly washed and cleansed within three hours after the completion of the slaughtering and dressing of any cattle therein, on any day during which any such slaughtering or dressing shall take place, shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*.

SEVENTH

Every Occupier of a Slaughter-house shall provide, keep, and from time to time maintain a sufficient number of tubs, boxes, or vessels, with tight or close-fitting covers thereto, constructed to the satisfaction of the engineer for the time being, for the purpose of receiving and conveying away from such Slaughter-house all manure, garbage, offal, and filth; and shall, immediately after the killing and dressing of any cattle in such Slaughter-house, cause all such manure, garbage, offal, and filth to be placed in such tubs, boxes, or vessels, and to be removed beyond the limits of the Borough of Liverpool, at least once during every day, to the satisfaction of the Medical Officer of Health for the time being; and any Occupier of a Slaughter-house who shall neglect or omit to provide, keep, or from time to time to maintain such number of such tubs, boxes, or vessels;

Or

Who shall neglect or omit to cause such manure, garbage, offal, and filth to be placed therein and removed in the manner, at the times, and beyond the limits aforesaid;

Or

Who shall neglect or omit to cause such tubs, boxes, or vessels, after being used for the purpose of such removal, to be thoroughly cleansed and purified before the same are again brought within the limits of the said Borough,

Shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such neglect or omission shall continue.

EIGHTH

The occupier of any Slaughter-house who shall slaughter, or permit or suffer to be slaughtered therein, any diseased or unsound cattle, shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*.

NINTH

The occupier of any Slaughter-house who shall, in case of any diseased or unsound cattle being brought to his or her Slaughter-house, neglect or omit forthwith to give information to the Inspector of Nuisances, at his Office, in the Public Offices, Cornwallis Street, in the said Borough of Liverpool, of such diseased or unsound cattle having been so brought to such Slaughter-house, shall, for every such neglect or omission, forfeit and pay the sum of *Forty Shillings*.

TENTH

The Occupier of any Slaughter-house who shall neglect or omit to remove, or cause to be removed from such Slaughter-house, the blood, hides, and skins of any cattle that shall be slaughtered in such Slaughter-house, within two days next after such cattle shall have been slaughtered, shall, for every such neglect or omission, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such neglect or omission shall continue.

ELEVENTH

The Occupier of every Slaughter-house shall keep, or cause to be kept therein, a book, in which shall be entered the number and description of all cattle slaughtered therein, together with the name and address of the owner of such cattle, or of the person bringing

such cattle to the said Slaughter-house; and shall, on Monday in each and every week, deliver or transmit to the Inspector of Nuisances for the time being, at his said office, a correct transcript copy or duplicate, signed by him, of all entries made in such book during the preceding week, and shall, at any and all times, on being requested so to do by the said Inspector of Nuisances, or any other officer of the said Council thereto authorised by the said Council, produce and show to the said Inspector, or other officer, the said book; and any occupier of a Slaughter-house who shall neglect or omit—

To keep, or cause to be kept, such book;

Or

To enter, or cause to be entered therein, the number and description of any cattle slaughtered in such Slaughter-house, or the name or address of the owner of such cattle, or of the person bringing such cattle to the said Slaughter-house;

Or

To deliver or transmit such transcript copy or duplicate in manner and at the times aforesaid,

Or

To produce and show such book to the persons, at the times and in manner aforesaid,

Shall, for every such neglect or omission, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such neglect or omission shall continue. And any person who shall make, or cause, or procure, or permit to be made any false entry in such book, or in such transcript copy or duplicate, concerning any of the matters or things hereby required to be entered or stated in such book or in such transcript copy or duplicate, shall, for each and every such offence, forfeit and pay the sum of *Forty Shillings*.

TWELFTH

Every Occupier of a Slaughter-house shall, on request by the Borough Engineer, Medical Officer of Health, or other authorised Officer of the said Council for the time being, forthwith cause all repairs in or concerning such Slaughter-house which he shall be required, by such request as aforesaid, to perform, to be done and executed to the satisfaction of the Borough Engineer, Medical Officer of Health, or other authorised Officer of the said Council for the time being; and any Occupier of a Slaughter-house who shall, for the space of one week after such request as aforesaid, refuse or neglect to cause such repairs to be so done and executed as aforesaid, shall, for such refusal or neglect, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such refusal or neglect shall continue.

THIRTEENTH

Any Occupier of a Slaughter-house who shall keep, or permit, or suffer to be kept, within such Slaughter-house, any dog,[1] without the same being well and sufficiently chained, fastened, and secured, shall, for every such offence, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such dog shall be so kept.

FOURTEENTH

The Occupier of every licensed or registered Slaughter-house shall cause the word 'Slaughter-house,' together with the number corresponding with the number of his licence or register, as the occupier of such Slaughter-house, as the same shall from time to time appear on the register of such licences, kept under the directions of the said Council, to be painted or otherwise inscribed, to the satisfaction of the Inspector of Nuisances for the time being, on, over, or adjoining to the outside of the door or entrances to such Slaughter-house, and kept and continued there not obliterated or defaced; and any Occupier of a

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[1] 'A dog harbours a tænia, and this parts with its last joint (proglottis) containing ripe eggs, or departs in person from the intestine. The proglottis or tænia may fall to the ground entire, with all the eggs in it, or the eggs may be laid by the proglottis already in the intestinal canal, and leave it in separate clusters mixed with fæces. These are now eaten by cattle or man with their respective raw or uncooked food. Arrived in the intestine, they are developed into embryos, which penetrate into the organs of the abdominal cavity and the chest, and are there developed into the cystic forms of echinococci.' 'The echinococci of cattle, particularly of sheep, are set free in the process of slaughtering; these are thrown on the ground and devoured by dogs, in them again to grow into ripe tænia.' (Dr. Thudichum on 'Parasitic Diseases of Quadrupeds used for Food by Man,' in the *Seventh Report of the Medical Officer of the Privy Council.*)

Slaughter-house who shall neglect or omit so to do shall, for each neglect or omission, forfeit and pay the sum of *Forty Shillings*, and the further sum of *Five Shillings* for each and every day, after the first, during which such neglect or omission shall continue.

FIFTEENTH

The Occupier of every Slaughter-house shall cause a copy of these Bye-Laws, written or printed in large characters, to be affixed in some conspicuous place in such Slaughter-house, to the satisfaction of the Inspector of Nuisances for the time being, and to be at all times kept and continued there not obliterated or defaced. And any occupier of a Slaughter-house who shall neglect or omit to cause such copy to be so affixed, kept, and continued, shall, for such offence, forfeit and pay the sum of *Forty Shillings*, and the sum of *Five Shillings* for each and every day, after the first, during which such neglect or omission shall continue.

The following is the form of licence held by the proprietors of the few private slaughter-houses allowed within the city of Liverpool, and it may be taken as the standard form employed throughout the country. No licence has been granted in Liverpool since 1877:—

CITY OF LIVERPOOL, *to wit.*

WHEREAS, by an Act passed in the Session of Parliament held in the ninth and tenth years of the reign of her Majesty Queen Victoria, intituled 'An Act for the Improvement of the Sewerage and Drainage of the Borough of Liverpool, and for making further Provisions for the Sanitary Regulation of the said Borough,' it was, amongst other things, enacted, that any person who should, within the Parish of Liverpool, kill or dress, for the purpose of trade, or cause or permit to be killed or dressed for such purpose, any Cattle, elsewhere than in certain Slaughter-houses erected as therein mentioned under the powers and authorities of a certain Act passed in the twenty-sixth year of the reign of his late Majesty King George the Third, or in a place erected or used for a Slaughter-house, under a licence for that purpose, granted by the Council of the said City, under the authority of a certain Act therein recited, for the Improvement, good Government, and Police Regulation of the City of Liverpool, and in force at the time of the killing or dressing of such Cattle, should, for every such offence, forfeit and pay a sum not exceeding Five Pounds, and the like penalty for every day after the first upon which such offence should be continued.

AND WHEREAS application hath been made to the Council, by of Retail Butcher, for a Licence for the killing and dressing of Cattle, in situate at within the Parish of Liverpool.

Now, the Council of the said City of Liverpool do, by these presents, grant a Licence to the said for the killing of Cattle, within the Parish of Liverpool, that is to say, within such part of the City of Liverpool as is comprised within the City, as the same was limited prior to the passing of an Act passed in the Session of Parliament held in the fifth and sixth years of the reign of his late Majesty King William the Fourth, and intituled 'An Act to provide for the Regulation of Municipal Corporations in England and Wales,' under the conditions, restrictions, and regulations following, that is to say,

1st. The said shall not kill or dress, or permit or suffer to be killed or dressed, any Cattle elsewhere, within the said Parish of Liverpool, than in the said .

2nd. The said shall not kill or dress, or permit or suffer to be killed or dressed at, or in the said Slaughter-house, any Cattle, except for sale in his shop to his ordinary customers, or to shipping, or for some other similar retail Butcher, who shall be Licensed by or under the direction of the Council.

3rd. If the said shall commit any breach of the said two hereinbefore mentioned conditions, or of either of them, this Licence shall thereupon forthwith become and be void, and of no effect.

4th. If the said shall be convicted of any offence within the City of Liverpool, against any of the provisions of any Act of Parliament, or of any Bye-law in relation to Slaughter-houses, or to the killing or dressing of Cattle within the said City, then, and in such case, this Licence shall, by any resolution of the Council to determine and make void the same, be and become void, on the expiration of one calendar month after service on the said of a notice in writing, of such resolution.

5th. This Licence shall, by any resolution of the Council to determine and make void the same, be and become determined and absolutely void, on the expiration of three

calendar months after service on the said of a notice, in writing, or of such resolution, as last aforesaid.

6th. The service of such notice, as is mentioned in the said 4th and 5th conditions respectively, shall be, either by the delivery of a Copy thereof to the said personally, or by leaving a Copy thereof at his Dwelling-house, or last known place of abode, within the City, or by affixing the same on the outside of the said .

7th. This Licence shall not be of any effect until the Certificate at the foot thereof shall have been signed by the Medical Officer of Health of the said City for the time being. , TOWN CLERK.

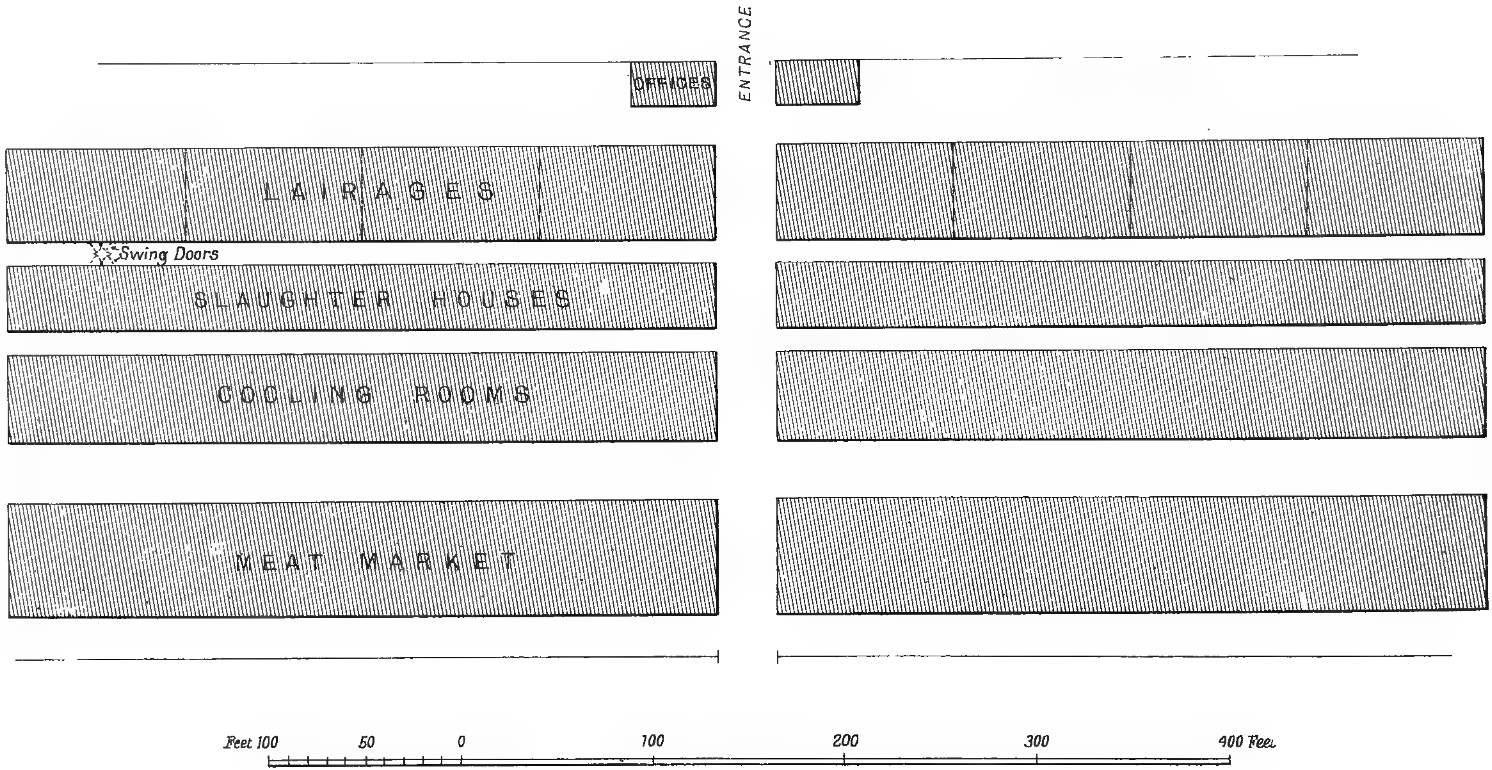
I hereby Certify that the in this Licence mentioned is in a fit and proper state and condition for the killing and dressing of Cattle therein.

Liverpool, the day of 18 .

Registered No. . , MEDICAL OFFICER OF HEALTH.

In London at the present time the requirements for private slaughter-houses are much greater under the London County Council than formerly. Overcrowding is prevented by insisting on 24 square feet of floor space in every pound for cattle, 8 square feet for calves, and 6 square feet for sheep, lambs, and pigs; and every animal must be 'provided with a sufficient quantity of wholesome water and food.' The bye-laws of the Council also contain provisions prohibiting the slaughtering of cattle in the public view, or in view of any other animal, and requiring the taking of precautions to prevent unnecessary suffering to the animal slaughtered. The usual provisions relating to the use of receptacles for the refuse products, the removal from the premises of these products, of the hides, tripes, and offal, and the cleansing of the premises and receptacles, are embodied in the bye-laws. Some of the more important requirements relate to the structure of the premises. The entrance or approach to every slaughter-house must be not less than 3 feet 6 inches wide, and the approach must not be up or down steps, nor over a steeper gradient than one in four. The entrance or approach to slaughter-houses for sheep, lambs, and pigs only, need not have a greater width than 2 feet 9 inches. The bye-laws also require the proper lighting, ventilation, paving, and drainage of every slaughter-house, pound, pen, and lair, and the provision of water supply, water fittings, and wall coverings; no room over a slaughter-house may be used for human habitation, nor may any water-closet, privy, urinal, or stable be in direct communication with, or ventilate into, a slaughter-house. The requirements for new slaughter-houses are still greater. The slaughter-house and its poundage must be at least 20 feet from any inhabited building, and must not have any entrance opening directly on a public highway. Every slaughter-house must have an adequate place for the accommodation or poundage of the cattle about to be slaughtered, with an entrance way for the cattle otherwise than through the slaughter-house; and the slaughter-house and its poundage must have an entrance apart from, and independent of, any shop and dwelling-house, and be properly lighted by lantern, sky, or side lights. The floor of the premises must not be below the level of the outside road or footway.

However excellent the construction of bye-laws may be, no profound experience or knowledge of the world is needed to show that the amount of attention paid to their requirements, and consequently the amount of good they are, will depend upon the stringency with which their provisions are enforced. Without active supervision, the slaughtering places of a town possessed of unimpeachable bye-laws will become centres of offence and a menace to the health of the locality; not only so, but they may furnish a ready means for the disposal of meat which is unfit for human food; but before referring to the question of inspection, the important subject of public abattoirs may be considered.



West, Newman lith.

Many towns, such, for example, as Huddersfield, Edinburgh, Manchester, Liverpool, Swansea, and other places, are possessed of public abattoirs, some of them being of recent construction, and others erected some twenty or thirty years back. Generally speaking, these places have been established in order to remove the evil which resulted from the number, and the then condition, of the private slaughter-houses in those towns. It was no doubt fully recognised that whatever steps may be taken to improve the health of a town by cleansing, scavenging, sewering and the like, they will be rendered ineffectual if slaughter-houses and the attendant and collateral trades are allowed to continue in densely populated quarters, and, as is commonly the case, in the narrowest and most ill-ventilated streets of those quarters. Consequently the aim appears to have been to limit the number of these places to the actual requirements of the people, and, as circumstances permitted, to effect their removal, and the transference of the business to more suitable surroundings.

The importance of an open site, where the various offensive emanations may be freely diluted with abundance of fresh air, cannot be too strongly insisted upon; and, when such a site is available, care must be taken to prevent, or at least control, the erection of dwellings adjacent to the slaughtering places; for we find that the abattoirs of several towns, those more especially which were established some twenty or thirty years ago, have been surrounded by dwellings, which in course of years have encroached upon what were originally open sites. As a consequence of this, the removal of public abattoirs sometimes becomes a matter for serious consideration, and, needless to say, it is a question less easy of solution than is the dealing with the smaller interests of a private slaughter-house. It may be remarked that the argument has been put forward against the removal of these places, that the transfer of carcases to any considerable distance, e.g. by rail, has a prejudicial effect upon the meat; but this is incorrect: indeed, the condition in which meat arrives from the United States or distant colonies, after thousands of miles of travel, provided due care is taken in packing and unpacking, sufficiently disposes of the objection.

The selection of a site would be further influenced by the facilities afforded for bringing cattle to it, and again by the means available for the removal and distribution of the meat. Consideration would also be given to the conveniences for dealing with hides, blood, intestines, and the like, and for such treatment of these and other products as it may be desirable to adopt.

The site to be preferred, then, would be one sufficiently removed from dwellings to ensure that all offensive vapours, whether from the animals themselves, or from blood, garbage, or the decompositions of washings and the like, should have abundance of fresh air for their dilution; it should include a sufficient number of acres, not only to meet present requirements, but to admit of extension of the premises as the population of the district increases and the trade expands; it should be ready of access, and, if the meat is intended for consumption in distant parts of the country, within easy reach of a railway.

The general plan of the arrangement of the various components of the business is simple. (See diagram, Plate VIII.) The cattle market, including lairages and pens for cattle, sheep, and pigs, would occupy about one-half the area; the remaining half will be occupied by the abattoirs proper, comprising slaughter-houses, parallel to and in the rear of which will be lairages which are duly separated therefrom, while in front of the slaughtering-places, and separated from them by a roadway some 12 feet wide, will be the meat market. The meat market may be connected with the slaughtering-booths by overhead meat-beams, the object of the roadway being to facilitate the removal of blood

and other materials, the meat itself being most conveniently removed from the opposite side of the meat market. This sketch is of course liable to many modifications. At Swansea, the abattoirs (see Plate IX.) are of stone with local 'polled stone' facing, lined internally with white glazed bricks to a height of 6 feet; above this the rubble-faced wall is white-limed. The floors of the killing houses and cooling rooms are of Wilkinson's patent granite concrete; but this being found to be slippery,[1] in a recent addition ordinary flags have been used with satisfactory results. The floors of the lairs are of blue stable bricks (Doulton's). Provision for artificial lighting is made by gas brackets, so placed as not to interfere with the hoisting and hanging machinery.

The site is bounded on three sides by streets about 30 yards wide, with no houses or buildings on the sides of the streets next the slaughter-houses. The lairs are only separated from the killing-houses by a passage 6 feet wide, this arrangement being made with a view to get the animals easily from the lairs to the slaughter-houses. The cooling rooms are to a certain extent used as a dead-meat market, the carcases being here sold wholesale and then conveyed to the retail market about half a mile away.

The cattle-market adjoins the slaughter-house buildings, and contains lairs for beasts and sheep, and also pig pens, all covered and protected from the weather; there being no open pens in the market.

At Huddersfield there is a similar proximity of the abattoir to the cattle market. Both are well situated in an open locality removed from dwellings. The premises are enclosed and are provided with an attractive approach. As in the preceding case, the lairages are appropriately separated from the slaughtering-place, the animals being driven in as required; the slaughtering-places are merely recessed off from the meat market. The floor is of concrete; the walls have white glazed bricks to a height of 8 or 9 feet, and there is a good north top light. The piggery, which is separate, is of similar construction, and is provided with steaming apparatus.

The total area covered by the slaughter-houses, yards, &c., is 7,198 square yards, of which 1,598 square yards are available for future extension. The cattle market covers an area of 1 acre 1 rood 12 perches; the animals passing through it last year were 8,438 beasts, 2,263 pigs. At the slaughter-houses during the same period, the number of animals killed was 5,255 beasts, 2,524 calves, 13,000 sheep, 5,985 pigs.

The planning, structure, and administration of these premises are all good.

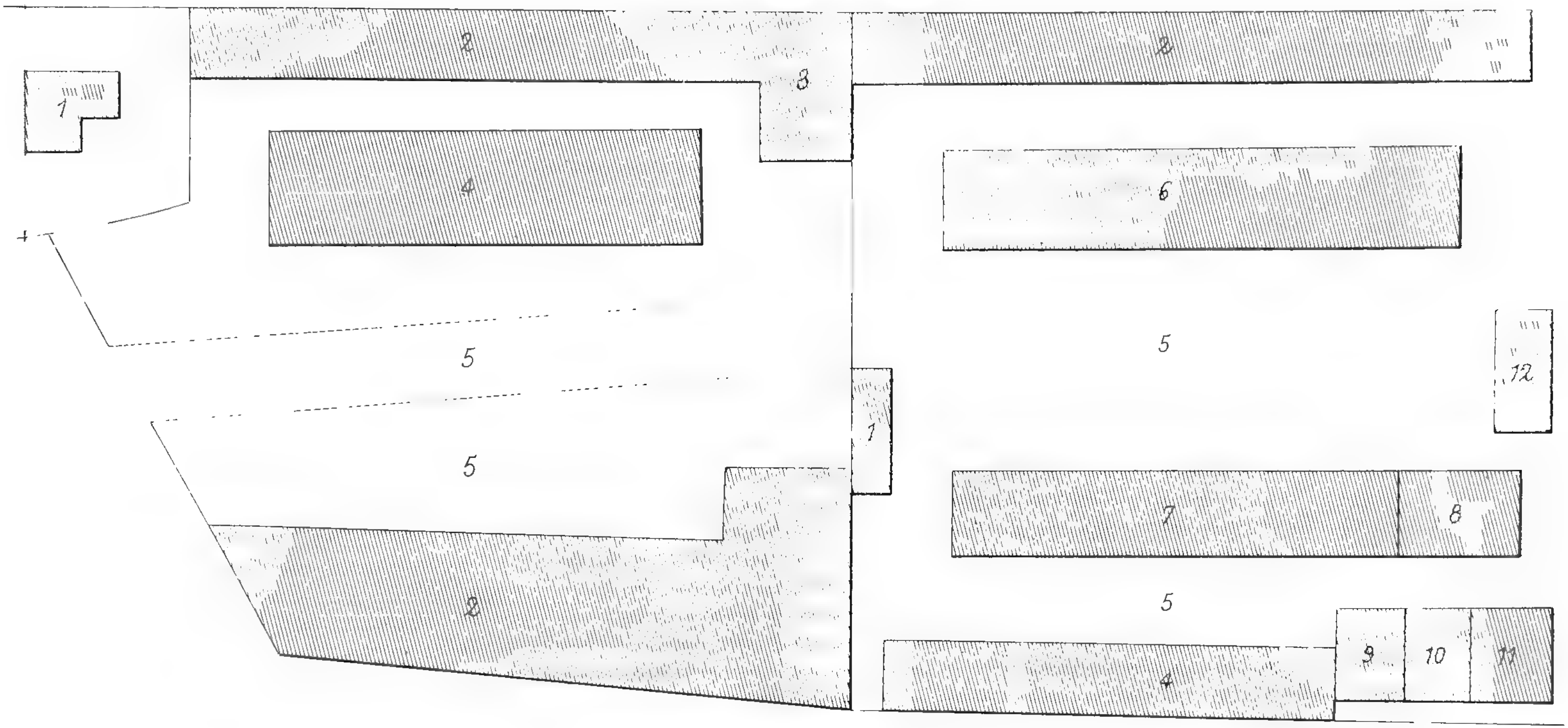
At Liverpool, although the management is good, the structure of the older parts of the abattoirs is defective, and the site, though excellent for a meat market, is not all that could be desired for an abattoir. The regulations of the Liverpool Abattoir Company are as follows:—

1. That the Lairs of the Abattoir Company are only intended for the accommodation of animals brought on to the Company's premises for the purpose of being slaughtered there; therefore, and for the purpose of preventing the spread of Cattle Disease, and the Abattoir being closed by orders of the Privy Council or otherwise, which would cause great loss and inconvenience to the Company and persons using the Abattoir, no Ox, Cow, Bull, Calf, Pig, Sheep, Lamb, or Goat, brought on to the Company's premises, shall be removed therefrom until after it is slaughtered.

2. That for the more conveniently carrying on the business of the Company, the Directors reserve power of appointing from time to time the most convenient hours for receiving animals, slaughtering, selling dead meat, and doing any other act, matter, or thing.

3. That during the time from 7 o'clock to 10 o'clock in the mornings of Tuesdays, Wednesdays, and Thursdays, and during the time from 4 o'clock to 6 o'clock in the after-

[1] Generally speaking, slipperiness can be overcome by a judicious sprinkling with saw-dust.



1 Keeper's House.
2. Lairages for Beasts.
3 " " Pigs.
4 Sheep Pens.
5 Roadways or Open Spaces.
11. Gut House.

6 Killing & Cooling Houses for Beasts
7 " " " Sheep & Calves
8. " " " Pigs.
9 Boiler House
10. Fat boiling House
12. Dung Pits

West Newman lith

noons of Mondays, Wednesdays, and Thursdays, no Cattle, Calves, or Sheep shall be brought on to the Company's premises except by either of the entrances Nos. 15, in Trowbridge Street, 16, in Copperas Hill, 19, 20, & 22, in St. Andrew Street, or into the Chapel and the Piggery; and no cattle shall during the same times be taken out of either of the North-end Lairs in Trowbridge Street or St. Andrew Street.

4. That the number of animals which may be brought into the Lairs, and from the Lairs or the Street or otherwise, into the slaughtering-place at one time by any owner, shall be regulated from time to time by the Directors or their Servant or Servants, in such manner as they may deem proper, for preventing overcrowding or inconvenience in the slaughtering-place.

5. That, except during such times as, in consequence of any Regulation or Order in relation to the prevention of Cattle Disease, the Directors shall otherwise direct, no animal shall be allowed to remain on the Company's premises unslaughtered for more than forty-eight hours.

6. If any animal is left on the Company's premises for more than forty-eight hours, except when the Directors shall otherwise direct as above-mentioned, and then for more than the time directed, without being slaughtered, the Directors or their servant or servants may cause such animal to be slaughtered, and charge the owner, or person who brought or caused to be brought such animal on to the Company's premises, with all costs, charges, and expenses incurred, in addition to any tolls or other charges; and may sell all or any part of the carcass, hide, skin, fat, offal, or other part of such animal, and, out of the moneys received therefor, retain and reimburse themselves the costs, charges, and expenses of carrying the powers and provisions hereof into effect, and all tolls, charges, and payments owing or payable to the Company by the owner of such animal, or the person or persons who brought or caused to be brought such animal on to the Company's premises or any other person in respect of such animal.

7. That all Cattle brought on to the Company's premises shall be tied up, and all animals shall be placed in such Lairs, and the slaughtering shall take place, and all carcasses and dead meat shall be hung, and all other parts of the animals shall be deposited, where and as the Directors or their servant or servants shall from time to time direct, as most conducive to the carrying on of the business of the Company and the convenience of the persons resorting to their premises.

8. That what are known as smothered animals shall (if fit for human food) be dressed as soon as possible after arriving at the Company's premises; and the several Bye-Laws, Rules, and Regulations shall (as far as applicable) be applied to such animals and their products, as if they had been slaughtered on the Company's premises.

9. Complaints have been made to the Directors of Cattle and other animals being kept on their premises an unreasonable time, without food and water; therefore, no animal shall be kept on their premises more than twenty-four hours without being fed and watered.

10. There shall be paid to the Company, in respect of animals slaughtered on the Company's premises, the following tolls or payments, viz.:—

for each Ox, Cow, or Bull	1*s.* 6*d.*
for each Sheep, Lamb, or Goat	$1\frac{1}{2}$*d.*
and for each Calf or Pig	6*d.*

and there shall be paid to the Company, in respect of every carcass brought on to the Company's premises but not slaughtered thereon, the following tolls or payments, viz.:—

of an Ox, Cow, or Bull	1*s.* 6*d.*
of a Sheep, Lamb, or Goat	$1\frac{1}{2}$*d.*
of a Calf or Pig	6*d.*

and for all dead meat in pieces less than a carcass, such sum as the Directors or their servants shall decide is a fair and just payment, in proportion to what is payable in respect of a carcass.

11. There shall be paid to the Company, in such cases as the Directors or their servants shall think fit to enforce the same, in respect of

each Ox, Cow, or Bull	3*d.*
each 20 Sheep, Lambs, or Goats	1*s.*
and a proportionate amount for any smaller number;	
each Calf	3*d.*
and each Pig	$1\frac{1}{2}$*d.*

for every twenty-four hours, or less time than twenty-four hours, beyond the first forty-eight hours, during which such animal shall remain on the Company's premises unslaughtered.

12. That if any animal shall be sold while alive and on the Company's premises, there shall be paid to the Company, in addition to all other tolls, rates, and charges, the sum of

for each head of Cattle	3*d.*
for each 20 Sheep, Lambs, or Goats	1*s.*
and a proportionate amount for any smaller quantity;	
for each Calf	3*d.*
for each Pig	1½*d.*

so sold.

13. Every person who shall slaughter, or cause to be slaughtered, any animal in or upon the premises of the Company, shall carefully collect or cause to be collected the blood flowing therefrom, in the utensil provided for that purpose by the Directors.

14. That every person so slaughtering, or causing to be slaughtered, as aforesaid, shall deposit and leave in such place or places on the premises as the Directors or their servant or servants shall from time to time direct, the Garbage, Gall, Blood, Intestines, Manifolds, Slinks, Pig's Hair, Rops, Sheep's Bellies, Bladders, and Manure produced from each animal slaughtered, excepting the Blood and Rops of Pigs.

15. That the Blood, Garbage, and other matters mentioned in the 14th Bye-Law, Regulation, or Rule shall be the property of the Company, and the same shall absolutely pass to and vest in the Company.

16. All former Bye-Laws, Rules and Regulations, made and issued by the Directors are withdrawn, and have ceased to take effect, except in respect to any act, matters, rights, duties, and liabilities before the making of these Bye-Laws, Rules and Regulations,

17. That each slaughterer shall, immediately after any slaughtering takes place, well and effectually sweep, wash, and cleanse the place used.

18. The Company will not be liable for the safe custody of any animal, dead meat, or other part of any animal, or any damage or injury to any animal, or dead meat, or other part of any animal, whilst on the Company's premises; and, for the purpose of this rule, the respective owners of animals, and dead meat, or parts of any animal, shall be deemed and considered to have the sole custody, care, and preservation of the same.

19. Any person making a false return to any of the Company's servants, of their weekly or other slaughter, will not be allowed to slaughter any more on any part of the Company's premises, or to bring thereon any animal, carcass, or part of any animal.

20. That the Company shall have a general lien on all live and dead animals, dead meat and parts of animals, for all moneys owing or payable to the Company in respect thereof by any person or persons whomsoever, and shall be entitled to enforce such lien by seizure and sale, without any further authority.

21. All persons while upon the Company's premises shall obey the orders of the Directors and their servant or servants, and shall behave in an orderly and proper manner, and shall attend to and conduct their business therein in such a way as not to cause annoyance or obstruction to any other person.

22. No person who has not proper and sufficient business to be on—or who shall not, on request, satisfy the Directors or their servant or servants that he has proper and sufficient business to be on—the premises, shall be or remain on the premises of the Company; and the Directors or their servant or servants shall be at liberty to forcibly eject from their premises all persons who do not, on request, satisfy them that they have proper and sufficient business to be on the premises.

23. The Directors, their servant or servants, shall be at liberty to forcibly eject from, and prevent from again coming on to the premises, any person who shall not observe, comply with, and conform to these Bye-Laws and Rules.

24. All dogs on the Company's premises during the time from 7 o'clock to 10 o'clock in the mornings of Tuesdays, Wednesdays, and Thursdays, and during the time from 4 o'clock to 6 o'clock in the afternoons of Mondays, Wednesdays, and Thursdays, and on Fridays, from 7 A.M. to 5 P.M., belonging to any person having animals, carcasses, or other dead meat, or to the servants of such persons, shall be securely chained, tied up, or otherwise confined, so that they may not cause annoyance or inconvenience to persons having business on the Company's premises.

Something more than a general impression with regard to the relative advantages of public and private slaughter-houses will have been derived from

the foregoing pages. If slaughtering and its attendant industries are offensive or liable to become so, or are of such a nature as to require jealous watching and careful administration to prevent them becoming injurious to health, it is clearly desirable to minimise the numbers of such establishments to the necessities of the trade. Furthermore, practical experience confirms the view that more economy and greater efficiency are found by centralising the trade in one well-conducted establishment, than can be looked for when every butcher slaughters in his own more or less ill-adapted back premises at irregular intervals to meet the requirements of a small retail trade. Again, the difficulties in the way of inspection, and the prevention of the sale of unsound meat, are greatly increased when supervision has to be extended to a multitude of small out-of-the way places, numbering as they do in one important town as many as 40, in another as many as 60, and in a third upwards of 200. Such conditions afford facilities for the disposal of unsound meat which are practically beyond the control of inspectors; and indeed the position in these cases is frequently still further complicated by the practice of licensing several retail butchers to kill on the same premises, thus putting still further obstacles in the way of fixing responsibility and preventing improper conduct. With the prompt and multiplied means of transit now available, there no longer exists any necessity for private slaughter-houses in towns, and it may be hoped that the establishment in their place of public abattoirs upon salubrious sites is merely a question of time.

We come now to the work of *inspection*, the objects of which are twofold, viz. (1) to insure that meat intended for the food of man shall be in good and wholesome condition, and (2) to provide for the observance of the bye-laws and the proper conduct of the business. The powers exercised by sanitary authorities are derived from several sources—viz. various local Acts, and bye-laws based upon them; the Contagious Diseases (Animals) Acts, and Orders of Council made thereunder; and the Public Health Act.

Public abattoirs will require the presence of the inspector, at least several hours a day if an extensive business is carried on. Visits should, of course, also be paid at irregular intervals. All private slaughter-houses should be visited at least once a day, oftener if the business is a large one. The twenty-eight private slaughter-houses in Liverpool are visited, some daily, others two or three times a day. As an index to the extent of business needing this supervision, it may be stated that the number of animals killed in these private slaughter-houses during the year amounted to 10,500 cattle, 45,000 sheep, 3,000 calves, and 48,000 pigs. At the public abattoirs the numbers killed in the same period were, 29,841 cattle, 192,000 sheep, 17,096 calves, and 22,000 pigs; large quantities of imported dead meat were also sold at these premises. In regard to the method of meat inspection pursued in Liverpool, the services of the Medical Officer of Health, his deputy, and the veterinary superintendent are all available when required, and in addition there are six meat inspectors, each of whom has a separate district and specific duties allotted to him, and is invested with authority, in conformity with the requirements of the several Acts already referred to. These inspectors are selected with great care from men physically fit, of unquestionable character, and with practical experience as butchers acquired in the public abattoirs, and are required to give proof of a thorough acquaintance with all classes of meat before undertaking the duties of inspector. Their salaries range from 120*l.* to 225*l.* per annum.

The officers of the Corporation exercise no control over meat in transit; and their responsibility is limited to animals slaughtered, or meat brought for sale within the city, whether intended for consumption within the municipal

boundary or not. It is almost unnecessary to remark that the mere presence of diseased meat upon licensed premises does not necessarily constitute a ground for prosecution; for, on the one hand, diseased animals are not infrequently sent to these places for convenience of slaughter and removal of the hides, &c.; and on the other hand, disease, such as *cysticercus*, which renders an animal unfit for food, may be incapable of detection during life, and be only ascertainable when the animal undergoes the process of dressing. In cases such as these, it is the duty of the person who is in possession of the carcase to remove it to some specified part of his premises, away from the place where meat is usually sold or deposited for the purpose of sale; the inspector then calls a jury of three members of the trade, who, with the owner, agreeing as to the condition of the meat, sign a certificate to that effect, and the meat is destroyed; no magistrate's order being necessary in these cases. A small fee is paid to the jurors who view the meat.

For reasons which are sufficiently obvious, it is preferable that suspected animals should be sent to the public abattoirs rather than to private slaughter-houses; disease existing in animals killed at the former place probably never escapes detection, and the chances of unwholesome meat being removed therefrom for consumption are practically nil.

With regard to the very different class of cases in which attempts are knowingly and intentionally made to dispose of unsound meat for human food, it is well to emphasise the provisions of sections 116, 117, 118, 119 of the Public Health Act, which enable the Medical Officer of Health or Inspector to examine *any* meat exposed for sale and intended for the food of man, *the onus of proof that it was not so intended lying with the party charged*; and the Act provides that, if such meat appear unfit for the food of man, the officer may seize the same in order to have it dealt with by a justice. It will be noted that the Act does not convert the Medical Officer or Inspector into an arbitrator whose function it shall be to *advise* dealers in meat what is sound and what is unsound, what may be exposed for sale and what may not, but it assumes that the dealer has a competent knowledge of his trade and merely directs the officer to seize what in his opinion is unsound, and have the matter decided by the magistrate.

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